REPORTS ON THE PROGRESS OF NAPHTHOLOGY DURING 1924.

Light Distillates.

By S. T. Card, B.Sc.

In the general field, as regards the actual constitution of the distillates, B. T. Brooks[1] has examined petroleum from the point of view of a chemical raw material. Young isolated normal- and iso- pentanes, hexanes and heptanes; cyclo-pentane, cyclo-hexane and methyl-cyclo-hexane have been observed in Baku distillates, and Midgley is stated to have detected dimethyl cyclo-butane in Californian gasoline. Brooks mentions the production of isopropyl alcohol from propylenes made from oil-gas, and chlorhydrins and drying-oils from cracked gases. C. R. Wagner[2] has examined the kerosenes from Mid-Continent crude by SO_2-extraction, and has obtained SO_2-soluble oils which nitrate violently. The presence of hydronaphthalenes is indicated. F. H. Rhodes and E. B. McConnell[3] have examined the vapour pressures of gasolines and other light distillates. Three methods of determining the naphthene-content of spirits have been compared by W. R. Ormandy and E. C. Craven.[4] These authors determined the values for various spirits, using Tizard's method of the lowering of the aniline point, a specific gravity method, and a refractometric method. The agreement between the three methods was fair, the last named usually giving slightly higher results. In connection with the solubility of petrol in water, L. H. Milligan[5] has determined that the solubility of hexane in 100 vols. of water at 25° C. is 0·0014 vol., and that the solubility of heptane is one-half this value.

Distillation and other characteristics of various light distillates from Persian crude (gasoline, kerosene and white spirit) are given in Dr. A. E. Dunstan's summary.[6] Some account of the hypochlorite refining scheme is also given, and this is amplified in a later paper.[7] This indicates the amount of sulphur removal,

[1] *J. Ind. Eng. Chem.* **16**, No. 2, 185-9.
[2] *J. Inst. Petr. Techn.*, 1924, No. 46, 220.
[3] *J. Ind. Eng. Chem.* **15**, No. 12, 1273.
[4] *J. Inst. Petr. Techn.*, 1924, No. 41, 101.
[5] *J. Phys. Chem.*, **28**, 494.
[6] *J. Inst. Petr. Techn.*, 1924, No. 41, 51.
[7] *Ibid.*, 1924, No. 46, 201.

and the necessary soda and hypochlorite treatments. G. R. Wendt and S. H. Diggs[8] examine the chemical methods for sweetening gasoline. The value of the plumbite wash (doctor treatment) and the function of the added sulphur is discussed, and an attempt to explain the chemical theory is made. Sweetening by hypochlorites is discussed. H. I. Waterman and J. H. Heimel[9] have investigated the action of hypochlorites on various sulphur-compounds dissolved in petroleum, with a view to elucidating the refining action of hypochlorites. That the fuel in an internal combustion engine is not responsible for the majority of the carbon is the view of A. P. Bjerrigaad.[10] This author states that, from the point of view of its efficiency as fuel, the usual specification for gasoline (*e.g.*, distillation range, degree of refining) can be disregarded. The lubricating oil causes the carbon in the cylinders. According to B. T. Brooks,[11] a brown discoloration on applying the doctor test to gasolines may be due to peroxides rather than to sulphur compounds. Cracked spirit which gives a negative test may give a positive (brown) test on standing. In such a case the addition of the sulphur caused no darkening in the colour.

In connection with natural-gas gasoline some of the constituents have been isolated by Anderson and Erskine.[12] These authors made fine fractionations, giving four portions containing the pentane, hexane, heptane and octane. Each of these fractions was three times fractionated. Sp. gr./B.Pt. curves and B.Pt./vol. curves are given for the distillates. In conclusion the estimated composition of their sample of natural gasoline is given as:— Propane and butane = 20 per cent.; *i*-pentane = 13 per cent., *n*-pentane = 17 per cent.; *i*-hexane = 9 per cent., *n*-hexane = 15 per cent.; *i*-heptane = 8 per cent., *n*-heptane = 12 per cent.; octane = 4 per cent.; absorption oil = 2 per cent. Many descriptions of natural gasoline plants have been published. R. T. Baker[13] describes a charcoal absorption process. It is stated[14] that one year's supply of coconut shells would, when carbonised, suffice for the daily production of 100,000 galls. of natural gasoline. Concerning rival extraction processes, D. E. Foster[15] compares compression and absorption processes, and states that it is less profitable to make natural gasoline by compression and then blend, than it is to make it by absorption and sell directly. The

[8] *J. Ind. Eng. Chem.*, Oct., 1924.
[9] *J. Inst. Petr. Techn.*, 1924, No. 46, 812.
[10] *Oil and Gas J.* **22**, No. 25, 113.
[11] *J. Ind. Eng. Chem.* **16**, No. 6, 588.
[12] *J. Ind. Eng. Chem.* **16**, No. 3, 262-7.
[13] *Oil and Gas J.* **23**, No. 12, 108 and 112; **23**, No. 3, 116-118.
[14] C. G. O'Refell and R. C. Alden, *Oil and Gas J.* **22**, No. 26, 76-80.
[15] *Oil and Gas J.* **23**, No. 20, 104-110.

two methods are also compared by G. A. Burrell[16] and E. H. Adams.[17] It is stated[18] that the absorption process is gaining in the Californian field, the author stating that the yield of gasoline here varies from 0·4 to 3·5 galls. per 1000 cub. ft. of gas, the average yield being 1 cub. ft., of end-point of 330-343° F. Much attention has been devoted to the stabilizing and blending of natural gasoline. J. C. Chatfield[19] describes a tower system of stabilizing. A tall column is filled with turnings or fitted with baffles, and the natural gasoline is allowed to fall down the tower. The expansion of the vapours leads to refrigeration and the higher-boiling constituents are condensed. The admission of steam at the bottom of the tower is claimed to improve the process, the "wild" gas leaving at the top of the tower. G. A. Burrell[20] discusses blending, and there are many patents covering the subject.[21] L. F. Boyr[22] describes a system of stabilizing natural gasoline by expansion in towers.

Much attention has been paid to evaporation losses from light distillates. A comprehensive survey of the question was undertaken by the U.S. Bureau of Mines.[23] It is estimated that in the Mid-Continent fields 6·5 per cent. of the crude oil produced is lost by evaporation, of which 3·5 per cent. is lost on the site and 3 per cent. in transportation. In ten days a loss of 9·3 per cent has been observed from the well to the refiner. In some cases the time between production and distillation may be 5·1 months, with a handling loss of 12·15 per cent. It was estimated that the cost of making gas-tight tanks would be covered in 30-90 days. One means of prevention of losses is stated by C. P. Buck[24] to apply a slight vacuum (4 in. of water) to all tanks and separators, the vapours to be collected and stripped. A 13·8 per cent. loss has been observed in open tankage. It is stated that at least 6 per cent. can be recovered by this means. D. B. Dow[25] describes methods of recovering the gasoline from uncondensed still vapours.

In connection with the repression of the tendency of gasoline to cause knocking in automobile engines, the theory that the anti-

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[16] *Petr. Age* **12**, No. 7, 48, 50-54; No. 8, 70.
[17] *Petr. World* **9**, No. 5, 100-102.
[18] C. J. von Bibra, *Refiner and Nat. Gas. Mfr.* **3**, No. 5, 13-15.
[19] *Nat. Petr. News* **16**, No. 16, 39.
[20] *See* [18].
[21] E. G. T. L. Kerr, U.S.P. 1,503,792.
[22] *Oil and Gas J.* **23**, No. 15, 32, 136.
[23] *Bulletin* 319, "Methods of Decreasing the Evaporation Losses of Petroleum," J. H. Wiggins. *See also* "Effect of Cooling Systems on Evaporation Losses of Gasoline," L. Schmidt, *Nat. Petr. News*, **15**, No. 42, 51-7, and "Petroleum Evaporation Losses," *Chem. and Met. J.*, 1924, **30**, No. 2, 55.
[24] *Petr. Age*, 1924, **13**, No. 2, 23-24.
[25] *Nat. Petr. News*, 1924, **16**, No. 7, 53-7.

knock substances act by absorbing radiation seems to be gaining ground. Thus C. E. Boord and R. E. Schaach[26] have obtained the hot-wire ignition curves for certain fuels, and have noted that the addition of the anti-knock substances has the effect of increasing the amount of energy necessary to put into the wire in order to obtain ignition. G. L. Wendt[27] thinks that the lead atoms in lead tetraethyl absorb electrons which are the accelerators of the flame propagation. He has shown that the presence of the anti-knock in an ionised air/benzene mixture has the effect of causing the ions and electrons to reunite. Midgley's collaborator, T. A. Boyd,[28] has investigated the anti-knock effect of various nitrogen compounds, principally amines, using the bouncing-pin apparatus. He shows that aromatic amines are superior to aliphatic, aniline being better than ethylamine. The toluidines and diphenylamine are good anti-knocks, but ammonia has a very slight effect. H. Kerr Thomas[29] has tried the use of lead tetraethyl with initial success, though later the deposit of lead compound caused serious trouble. It is known that the anti-knock was always mixed with an organic halogen compound when sold in America, in order to form volatile lead halide, which is stated to lead to no ill effect on the engine. S. F. Birch[30] gives a method of estimating lead tetraethyl in motor spirit. E. Sokal[31] gives an account of results of using his method of repressing detonation. The combustion-chamber is coated with "Katalite," a mixture of metallic oxides. G. A. Young and J. H. Holloway[32] describe engine tests with anti-knocks.

Heavy Distillates.

By HAROLD MOORE, M.Sc.(Tech.), A.I.C., F.C.S.

THE more important advances made in the technology of heavy distillates and residues are those of an engineering nature connected with the use of such products. The straight-run heavy distillates mainly find application as gas oils, raw material for cracking plants, or fuel oil. The fuel oils, the majority of which are either residual or mixtures of gas oil and residue, call for

[26] *J. Ind. Eng. Chem.*, Oct., 1924.
[27] Summarised in *J. Ind. Eng. Chem.* (News Edn.), May 10, 1924, and *J. Ind. Eng. Chem.* **16**, No. 9, 890.
[28] *See* No. 27 and *J. Ind. Eng. Chem.* **16**, No. 9, 893.
[29] *Auto. Engr.*, Oct., 1924.
[30] *J. Inst. Petr. Techn.*, 1924, No. 46, 817.
[31] *See* No. 27.
[32] *J. Soc. Automotive Engrs.*, 1924, **14**, 315.

comparatively little technical skill in their preparation, being mainly composed of fractions which are not required for other purposes.

A point of considerable importance to all interested in fuel oil is the appearance during the past year of a series of specifications of standard fuel oils for heavy-oil engines. These specifications have been prepared by the British Engineering Standards Association.[1] Four specifications are given :—

"A." This is very rigid and will require a low viscosity oil of low asphalt content to meet it.

"B." A specification which allows a more asphaltic and higher-viscosity oil.

"C." This is still less rigid.

"D." This is constructed to allow fairly heavy asphaltic oils of the furnace-oil class to pass.

The specifications are such that, apart from the question of flashpoint, the requirements of the Admiralty are met by specification "A," and to a lesser extent by "B," but not by "C" and "D."

For all four types of oil the minimum flashpoint limit is 150° F. (the Admiralty limit is 175° F.). The hard asphalt content, which is probably the most important point in these specifications, varies with each grade, the higher quality "A" requiring to have a hard asphalt content not exceeding 0·5 per cent., and "B," "C" and "D" being limited to 2, 4 and 12 per cent. respectively. As regards ash content, the "A" grade is limited to 0·01 per cent. —a point which practically forces suppliers to tender gas oil in order to ensure being below this limit. For the other three qualities the ash limit is 0·05 per cent., a figure which suppliers will have difficulty in meeting on the highly asphaltic fuel oil permissible under specification "D." For the four oils the viscosity at 100° F. by the Redwood instrument is limited to 75 secs., 250 secs., 750 secs. and 1500 secs. respectively. The water content is limited to 0·5 per cent. for the superior grade and 1 per cent. for the other grades. The cold test is 20° F. for the lighter oil, while the "B," "C" and "D" oils have tests of 35° F., 40° F. and 45° F. respectively.

Although no minimum limit is put on the heat value for the various grades of oil, a footnote in the specification assures buyers that "A" and "B" qualities will possess at least 19,000 B.Th.U. gross per lb., while the other two oils will give 18,750 and 18,500 B.Th.U. gross per lb. respectively.

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[1] No. 209, 1924.

The publications of the Diesel Engine Users' Association this year are of considerable interest.

The annual report on the working costs of a number of heavy-oil engines[2] has again appeared, and gives authentic figures of considerable importance.

Thirty-four power stations have submitted figures of costs for tabulation, and in addition to this there is a lengthy communication from the Alexandria Water Company giving in detail the comparative figures relating to the working cost of Diesel and steam pumping installations. The average engine cost per unit generated has improved from 0·087d. to 0·899d., the main reduction being due to the lower price of lubricating and fuel oils. The average fuel consumption works out at 0·748 lb. per unit generated, with an average running load factor of 57·7 per cent., this result being slightly poorer than that recorded in the previous report. Assuming that the average gross heat value of the fuel oil used is 19,500 B.Th.U. per lb., the over-all thermal efficiency taken on 129 engines of from 1000 b.h.p. capacity downwards works out at 23 per cent., which figure excels that of the best modern steam station cited in the publication of the Electricity Commissioners on the Generation of Electricity in Great Britain. The year has seen a large number of installations adopting systems for the recovery of lubricating oil, the majority of stations employing high-speed centrifuges. The results, however, do not yet come into ther period of working costs, so that the result of the use of high-speed centrifuges has not had effect on the report in question. The report is of the greatest value as giving unquestionable figures on the actual costs of working Diesel engines, and is therefore of much greater use than the figures obtained from oil-engine suppliers.

The report of the Alexandria pumping station shows the total cost per million foot-tons of work done to be £2 17s. 3d. on the Diesel engine pumping plants, against £7 on the steam pumping plant.

An excellent review of recent oil-engine development has been given in a somewhat lengthy and detailed paper by Chaloner.[3] This paper deals with both marine and land types of Diesel, cold starting and semi-Diesel engines. In his conclusions Mr. Chaloner remarks that most marked progress is at present being made in the marine world, and that in view of the fact that the marine engine is of later development than the stationary engine it is surprising that 3000 i.h.p. marine engines are standard as against 1000 i.h.p. in the case of stationary sets. In view of the fact that marine conditions are more arduous than land conditions, this progress is a very positive testimony to the success of the marine oil

[2] Annual Report on Heavy-Oil Engineering Costs, 1923–4.
[3] Paper read before the D.E.U.A., April 17, 1925.

engine in general. There is little doubt that the experience gained in marine work will give an impetus to the construction of larger sets for central power station work. The tendency in constructive development leans in the direction of two-stroke cycle double-acting, combined with the mechanical injection system. Chaloner is of the opinion that 380 lbs. per sq. in. is a safe practical limit for ignition purely by the heat of compression.

P. H. Smith[4] has dealt with the use of pyrometers to determine exhaust temperatures of oil engines as a means of checking their efficient working and also as an aid to the adjustment of the valve timings, pulveriser timings and blast pressure. Mr. Smith observes that the exhaust temperatures of Diesel engines are lower when tar oil (coal-tar creosote) is being burned. This is probably accounted for by the lower viscosity of the tar product, causing more efficient spraying and consequently more efficient combustion of the fuel.

High-speed heavy-oil engine electric generating sets have been the subject of a paper by Holliday.[5] The majority of the sets under consideration were submarine sets taken from enemy submarines at the end of the war and installed in this country. These engines have been run at reduced speeds and at lower ratings, and have been found to give considerable satisfaction for power production in this country.

A brief description of the development of the heavy-oil engine and its use for marine purposes was given in the President's valedictory address and on the use of petroleum with special reference to the production of power.[6] This address, which contains a brief résumé of the oil-engine position and the rapid development in the use of Diesel engines for marine purposes, shows that whereas in 1919 the number of Diesel motor ships afloat represented 2 per cent. of the total power ships, this percentage increased to 18·8 per cent. in 1924. The number of engines of various types is also given, showing the preponderance of the Burmeister and Wain type for marine propulsion, these being four-stroke cycle air injection engines.

In connection with the use of heavy fuel oil probably one of the most marked developments of the last year has been the increased use of centrifuges for purification of fuel prior to its entering the engine. A brief description of the effects of centrifugal treatment of fuel oils has been given by Moore.[7] The main object of the centrifugal treatment is to remove water almost entirely and a considerable proportion of the ash present in the

[4] Paper read before D.E.U.A., October 3, 1924.
[5] Paper read before D.E.U.A., February 13, 1925.
[6] Inst. Pet. Tech., No. 49, Vol. II., 1925, p. 104.
[7] *Motorship*, June, 1924, p. 82.

original fuel oil. As water is a very undesirable constituent in oil-engine fuel on account of the misfiring resulting from its presence, and as the ash content is the main cause of wear on the piston and cylinder walls, it is found that greater reliability and also greater economy of working is obtainable on oil engines when the fuel oils are previously treated by centrifuges. Whereas a few years ago the use of the centrifuge for fuel oil treatment was almost unknown, it is now almost standard practice for marine work and is also rapidly being adopted for land work. It is of particular importance for marine work, as motor-ships filling bunkers at various ports are never quite sure as to the quality of the oil, and the centrifuge is therefore of exceptional value. Whilst for light oils of the Diesel-engine class the centrifuge acts as an insurance against supplies of oil with high water or ash contents, it has been found that it is almost essential when attempting to run engines on the highly asphaltic boiler fuel oils such as heavy Mexican fuels and some of the fuels of Venezuelan origin. Centrifuges are also to a smaller extent being used for the purification of furnace oil required for external combustion in marine work.

Brunler[8] has described experimental work on an internal combustion boiler. Instead of the flame being applied to the external surface of the boiler, the fuel is actually burned in contact with the water. If required the steam can be superheated by means of a small burner situated in a steam reservoir over the surface of the water. Air is supplied by means of pressure. Brunler points out that tests are frequently obtained indicating an efficiency higher than the theoretical efficiency of the fuel as determined by analysis and determinations of calorific value. This method of heating has also been used for the concentration of chemical solutions and for the drying of peat.

A method of calculating the calorific value of liquid fuels has been prepared by Morpurgo.[9] He makes use of the formula cal. val.$=(11{,}200a-10{,}300b-8140c-2500s-10{,}000d)_2100q$, in which a and b are the fractions of hydrocarbons obtained by the Engler distillation up to 110° and from 110° to 310° respectively, d is the distillation residue less coke and ash, c is the coke value and s the sulphur content, the proportion of each constituent being multiplied by its average heat of combustion. Details are given of the methods of determining coke value and sulphur content. When a sample of oil is available it would probably be quicker and more reliable to ascertain the calorific value by direct experiment in the bomb.

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[8] *J. Inst. Petr. Techn.*, 1925, 41A.
[9] *Mitt. Staatl. Techn. Versuchsamts*, 10, 97–99.

Lubricants, Lubrication and Insulating Oils.

By R. W. L. Clarke, B.Sc., F.I.C.

A survey of the literature published in this branch of the subject shows that although no very striking developments are to be recorded during the period under review, the accumulation of valuable information proceeds steadily. The following is a brief *résumé* of the publications which appear to be of chief interest.

Preparation and Refining of Lubricating Oils.

Vacuum distillation of crude oils is advocated by Grady Triplett,[1] who describes the Schulze process, which operates under a pressure of not more than 25mm. of mercury throughout the system. Cuts are made according to the viscosity instead of the gravity of the distillate. Better fractionation is obtained than when distilling by fire and steam alone, and no acid treating of the overhead distillates is said to be necessary. L. Gerurtsch and B. Kaimer[2] have compared the lubricating oil distillates prepared from the same source with the aid of superheated steam, oil gas and flue gas respectively. Oil gas was found to minimise thermal decomposition during distillation to a greater extent than flue gas or steam.

W. S. Zehrung[3] points out the advantages of contact filtration over the older percolating filtration method. In this method of applying refining agents, the filtering agent or clay is agitated with the oil at a suitable temperature and the mixture passed to a filter press. H. Moore[4] prepares pale oils by adding approximately 2·5 per cent. of clay to spindle distillates, immediately after acid treating, agitating and heating to 250°—300° F. and filter-pressing. Sulphonic acids are completely removed by the clay. The oils have a better colour than when the neutralisation is effected with caustic soda. H. L. Kauffmann[5] discussed the *rôle* of adsorption in petroleum refining, and recommends upward filtration instead of the more usual downward percolation for the refining of oils by granular adsorbents. The characteristics, Sp. Gr., viscosity, etc., of a cylinder stock filtered by this anti-gravity method through fuller's earth are given at different stages during a batch filtration. Carl J. von Bibra[6] deals with the use and preparation of adsorptive

[1] *Ref. and Nat. Gas. Mfr.*, **3** (2) 23.
[2] *Chem. Abstr.*, **19**, 723.
[3] *Nat. Petr. News*, **16**, (23) 27.
[4] *Oil Engineering and Finance*, **5**, 357.
[5] *Chem. and Met. Eng.*, **30**, 153.
[6] *Ref. and Nat. Gas. Mfr.*, **3**, (6) 9 and (7), 15.

clays in two most interesting articles. These clays are employed in the contact filtration manner—*i.e.*, agitation with the oil at elevated temperatures followed by filter-pressing. The clays discussed are of two classes, natural clays of high adsorptive power, such as Death Valley Clay and clays of the type of the French mineral Montmorillonite, which have but little activity in the natural state, but become highly active after treatment with dilute sulphuric acid. The method of application of the latter class of refining agents appears to be a distinct advance and embodies some novel features. The clay is treated with sulphuric acid (25 per cent. H_2SO_4). The insoluble portion of the clay is then washed with water to remove the bulk of the reaction products. The washed clay may be dried and used as a natural clay or better employed in the form of a mud or slurry. Hence the process is called the Mudded Clay Process. The oil to be refined is given an acid treatment and washed with a water spray and then thoroughly mixed with the mudded clay. The mixture is then passed through a heated pipe-still into an agitator where it is subjected to the action of dry steam. Water, light oils and cracked products are driven off and the dry mixture of oil and clay is passed to a filter press where the clay is removed in a dry cake. The oil leaving the press is dry and of good colour, and will comply with the usual acidity specifications.

Properties of Lubricating Oils and Lubrication.

E. M. Johansen[7] has determined the interfacial tension between a number of petroleum products and water. Attention is drawn to the marked effect of minute traces of acidic bodies in causing a reduction in the value of the interfacial tension. Increase of temperature and the presence of bodies that are adsorbed at the interface also cause a similar reduction. In general, refining a lubricating oil stock raises the value of the interfacial tension. A knowledge of this tension is found useful when dealing with problems connected with lubrication and emulsions.

The influence of temperature on viscosity has been studied by A. E. Fortsch and R. E. Wilson,[8] who have determined the viscosity of the lubricating oil fractions from Mid-Continent and similar crudes at temperatures up to 495° F. A method of interpolation is suggested by which the viscosity of any oil up to 550° F. from an intermediate base crude can be arrived at with some accuracy from a single determination of its viscosity at ordinary temperatures. F. W. Lane and E. W. Dean[9] have amplified their earlier work and publish the results of temperature viscosity determinations on the

[7] *Ind. and Eng. Chem.*, **16**, 132.
[8] *Ibid.*, **16**, 789.
[9] *Ibid.*, **16**, 905.

distillates from five typical American crude oils. They arrive at the conclusion that for the lubricating distillates from a given crude, a single determination of the viscosity at a suitable temperature, together with a knowledge of the gravity at 60° F., is sufficient to determine the temperature-viscosity relationship over a wide temperature range.

A. E. Becker[10] discusses the results of Tower (published in 1883) on film lubrication in the light of more recent knowledge.

D. P. Barnard, H. M. Myers and H. O. Forrest[11] have continued their work on the mechanism of lubrication, and publish results showing the effect of the oiliness of the lubricant on the carrying power of a journal bearing. Oiliness was estimated comparatively by determining the static friction existing between two metallic surfaces wet with the lubricant under investigation. The coefficient of friction was measured by the torque imparted by a rotating journal to a cylindrical bushing floating on it. The authors conclude that the transition from stable to unstable lubrication—*i.e.*, from film to boundary lubrication—is altered by the oiliness of the lubricant, and that the transition point occurs at a lower value of zn/p (z=viscosity of lubricant, n=r.p.m., p=nominal pressure on the bearing) when oiliness as indicated by the coefficient of static friction is increased. The variation to be expected with commercial lubricants is small and certainly not over 10 per cent. The results are much affected by changes in the clearance between the journal and the bearing. R. von Dallwitz-Wegner[12] states that detrimental friction losses in a lubricated bearing depend not only on the viscosity of the oil, but also on the spreading power of the lubricant. The amount of lubricant required is proportional to the cube of the spreading power of the lubricant. A method of determining the spreading power consists in observing the fall in height of a column of the lubricating oil in a capillary glass tube when the bottom open end of the tube is repeatedly touched on a clean metal surface of the bearing alloy.

The lubrication of various machines has engaged the attention of many writers. Many articles in the technical Press are devoted to the problem of the satisfactory lubrication of automobile engines and the attendant problem of crank-case dilution. H. D. Nickinson,[13] in an article which is of great interest, records the results of observations made on the lubrication of the internal-combustion engines of commercial vehicles. Seven different suitable oils were used as crank-case lubricants in different vehicles

[10] *Ind. and Eng. Chem.*, **16**, 856.
[11] *Ibid.*, **16**, 347; *cf. Ibid.*, **14**, 347 and 682.
[12] *Chem. Abstr.*, **18**, 1902.
[13] *Automobile Engineer*, **14**, 24.

of the same type, and the observations were continued over very lengthy mileages. Oil and petrol consumptions, dilution, cylinder wear, and the weight of carbon deposits are given. The results showed that the cheapest oil gave as satisfactory service as the most highly refined. J. B. Rathburn[14] gives the results of dynamometer tests carried out on an automobile engine—determination of the horse-power output at the driving wheels—immediately after the crankcase had been drained and refilled with fresh oil. The car was then taken into ordinary service, and the horse-power output determined at intervals during a period in which the distance run amounted to 1,465 miles. After a mileage of 291, a considerable increase in the power output was observed particularly at high speeds. Some slight falling off of power with distance run on the same charge of oil is recorded, but in general the power output was greater with used oil than with the fresh oil. It would appear that the main cause of the increased power output is reduction in the viscosity of the oil by fuel dilution. This view is supported by the observations of L. H. Pomeroy,[15] who, when dealing with friction losses, petrol consumption and thermal efficiency, states that the beneficial effect of radiator shutters is almost entirely due to reduction in the viscosity of the oil owing to the higher working temperature. J. B. Hoblyn,[16] while discussing the behaviour of lubricating oil under oxidising tests, points out the importance of the evaporation test for determining the suitability of oils for internal-combustion engine lubrication. The results of engine tests are given and the author discusses the progressive decomposition of a lubricating oil in service. A method for the testing of lubricating oils is developed, which consists in heating the oil in crucibles at 250° C. removing a sample at intervals, placing a drop between cover glasses, and examining it microscopically, when the decomposition which the oil has undergone may be determined from its appearance. Several papers on crankcase dilution were read at the summer meeting of the Society of Automotive Engineers.[17] M. MacCoull discussed the relation between oil temperature and dilution, and R. L. Skinner described an oil rectifier as an accessory to the engine, which prevents the fall in viscosity by limiting dilution.

Turbine lubricating oil has been the subject of a number of communications. A. Duckham and S. E. Bowrey[18] deal with the effect of oxidation on the demulisibility of turbine oils. Oxidation causes the production of bodies which stabilise emulsions of

[14] *Pet. Age.*, **14**, (15) 54; *Abs.*, 11, 19A (1925).
[15] *J. Soc. Automotive Eng.*, **14**, 307.
[16] *Journal I.P.T.*, (1925), **11**, 1.
[17] *J. Soc. Automotive Eng.*, **15**, 43 *et seq.*; also *Nat. Petr. News*, **18**, (51), 39.
[18] *Engineering*, 116, 353 (1923).

oil and water. Oils which are equally good when fresh exhibit great differences after oxidation. N. E. Funk[19] points out that the mechanical devices for turbine lubrication have reached a more satisfactory state than the lubricants themselves. The importance of low viscosity, resistance to organic acid formation, sludging and emulsification for turbine oils is stressed.†

Insulating Oils.

The chief interest in connection with transformer oils is undoubtedly, judging by the number of articles on the subject, the oxidation or sludging test. The importance of this test is fully recognised by transformer users and oil producers, and will continue to be so until some satisfactory means is devised of preventing access of air to the hot oil in a transformer. There appears to be great difficulty in devising a test which approximates to the service conditions and which can be carried out in a reasonable time. The standard specifications for carrying out the sludging test vary in different countries.

Temperatures vary from 100 to 150° C. Oxygen or air is bubbled through the hot oil in some cases, but not in others. Some specifications demand the use of copper as a catalyst while others omit it. The times of heating also vary, the shortest being the British Michie test of 45 hours' duration. W. H. Nuttall[20] advocates the determination of the interfacial tension between transformer oils and 40 per cent. sulphuric acid as a measure of the amount of unsaturated bodies present in the oil. Experiment shows that the interfacial tension is inversely proportional to the actual sludge value. The Swedish General Electric Co.[21] publish results of studies on the influence of both temperature and electric field on the stability of transformer oils. Samples of oil were maintained at 90° C. for 6 months both with and without the influence of an electric field. Access of air was allowed. At the end of the period the sludge and tar values of the oil which had been exposed to the electrical stress were approximately double that of the oil which had only been kept hot. A new method for testing transformer oils is suggested. The oil is maintained at 100° C. for 100 hours, and is under the influence of an electric field of

[19] *Ind. and Eng. Chem.*, **16**, 1080.
[20] *World Power*, **2**, 92; *Abs.*, **11**, 9A (1925).
[21] *Assn. Jour.*, Nov. and Dec., 1924; *Abs.*, **11**, 19A (1925).

† See also H. Bromley (*Power*, **59**, 524) and F. A. Hoff (*Oil News*), **11**, (17), 15); also discuss the properties of turbine oils. H. Dimmig (*Proc. Am. Soc. Testing Mat.*, **23**, I., 363), Emulsifying tendency of lubricating oil surface tension method.

10 KV per cm., while oxygen is bubbled through the oil at the rate of 1 litre per hour.

E. A. Snyder[22] has devised a life test for transformer oils, which in outline is as follows: 500 cc. of the oil to be examined is placed in a beaker on a rotating table in an electrically heated oven, thermostatically controlled at 120° C. Samples of oil are withdrawn daily and examined. The number of days which elapse before any sludge appears is recorded as the result of the life test. H. Stager,[23] during an investigation on transformer oils, has subjected a number of oils to extraction with methyl alcohol. The alcoholic extracts contain unsaturated bodies which yield products of high acidity and considerable sludge on oxidation. The insoluble portion still gives considerable sludge with copper at 112° C. The methyl alcohol extracts bodies which are deleterious to cotton insulation. Jan Hladky[24] finds that treatment with bleaching powder will produce oils sufficiently refined to conform to the German tar-number of Kissling test.

The influence of the presence of metals on the oxidation of oils of the transformer or turbine type has been studied by a number of workers. In general, the presence of metals such as copper, iron, lead, etc., is found to catalyse the production of sludge. H. Stager[25] has determined the effect of the presence of various metals on sludge production. Deposits are favoured by the presence of copper, brass, constan, tin and zinc. Sodium, iron and aluminium produce no effect. Lead produces an acidic resinous reaction product which attacks the metal; oxidation effects follow. H. von den Heyden and K. Typke[26] give the results of experiments in which oxygen was bubbled through transformer oil at 120° C. for 70 hours in presence of bright copper, brass, oxidised copper, etc. The sludge in most cases consists of metallic soaps. The product of the acid value and the sludge value is suggested as a convenient device for expressing the effect of the metal on the oil. The results are stated to be also applicable to turbine oils.

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[22] *Proc. Am. Soc. Testing Mat.*, **23**, I., 448.
[23] *Chem. Abs.*, **18**, 164.
[24] *Ibid.*, **18**, 2243.
[25] *Ibid.*, **19**, 723.
[26] *Petroleum*, **20**, 320; *Abs.*, **10**, 173a.

Special Products.

By F. G. P. Remfry, B.A., D.Sc., A.I.C.

Activated Carbon.—Previous investigations by Ruff[1] led him to the conclusion that the activity of charcoal was influenced by the content of foreign atoms or groups. Improved analytical procedure, however, has now proved this view to be erroneous.[2] The type of furnace used and the nature and rate of passing the activating gases over the coal were found to greatly affect the resulting activity. Of activating gases CO_2, NH_3, SO_2 and H_2O were found to be the most effective. Brandis[3] considers that amorphous carbon exists in both active and inactive forms, of which only the former, produced by decomposition of organic compounds at a temperature below 500° C., has the power of adsorption. At temperatures above 500° C. transformation of active into inactive carbon takes place, and therefore an active carbon that has become saturated with adsorbed hydrocarbons cannot be revived by heat alone since these hydrocarbons are not expelled at temperatures below 500° C. During the process of manufacture, also, a certain amount of the active form is rendered inactive by adsorption of hydrocarbon vapours formed during the process.

Working on the activation of coal-like substances Fischer and Zerbe[4] found that the most active substance was obtained when coke from Alexandria lignite was treated with hydrogen and flue gas at a temperature of 900° C., being then capable of adsorbing 10 per cent. of its weight of light oil. According to the researches of Firth, Farmer and Higson[5] there appears to be no direct relation between the activity of carbon and the molecular complexity of the original carbon compound from which it was produced, a large number of carbons from different sources being found to give very similar results as regards activity. They describe a method for preparing a highly active carbon from wood charcoal by means of fuming nitric acid.

Lowry[6] determined the hydrogen content of charcoals, made from anthracite, which had not received an activation treatment.

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[1] *Kolloid Zeit.*, 1923, **32**, 225.
[2] Ruff, *ibid.*, 1924, **34**, 135.
[3] *Het. Gas.*, 1924, **44**, 5.
[4] *Brennstoff-Chem.*, 1923, **4**, 353.
[5] *J. Chem. Soc.*, 1924, **125**, 488.
[6] *J. Amer. Chem. Soc.*, 1924, **46**, 824.

In these amorphous carbons the carbon content appears to be high and the hydrogen low, whilst the volume of the pore spaces was found to decrease in the diminution of the hydrogen content.

During work on a commercial method for testing decolourising carbons, Teeple and Mahler[7] showed that Freundlich's adsorption law held good for all carbons and solutions examined. The adsorption of colour by carbon is definitely an equilibrium reaction which, however, is influenced by the presence of other materials.

A general theory of adsorption by charcoal has been propounded by Bartell and Miller[8] in which they suppose that the surface of the charcoal is covered with an adsorbed layer of OH and H ions, of which the former can be displaced by anions—especially organic anions—whilst the H ions can only be displaced by cations of metals more noble than H or of valency greater than two, or by organic cations.

Philip and Jarman[9] found during work on testing charcoals for activity that a marked increase occurred if facilities for access of air during carbonisation were given.

Paraffin Wax.—For the purpose of testing the purity of liquid vaseline or paraffin wax Richard[10] showed that the 60 per cent. sulphuric acid standardised by the French Codex has no action on even grossly impure samples, and recommends the use of acid of sp. gr. 1·84. When samples to be tested are shaken or rubbed up in the cold with double their weight of this acid the mixture should not be of more than a pale yellow colour at the end of one hour. Waterman and Perquin[11] have studied the decomposition of paraffin wax under heat treatment. Wax was heated to 450° C. under pressures varying from 7 to 219 kg. per sq. cm. in the presence of hydrogen, methane, nitrogen or a mixture of carbon monoxide and steam. The relative amounts of gas, gasoline, kerosene and residue boiling above 300° C. obtained under different conditions were recorded.

The solidification temperatures of different paraffin waxes found in Grozny residuum have been investigated by Tyeinin[12], who found that the solidification points were increased to a maximum by heating the samples to temperatures between 40° and 70° C. Further heating lowered the solidification point, but on allowing this superheated wax to stand it spontaneously acquires the higher solidification point.

The production of aromatic compounds from paraffin wax has

[7] *J. Ind. Eng. Chem.*, 1924, **16**, 498.
[8] *J. Phys. Chem.*, 1924, **28**, 992.
[9] *Ibid.*, 1924, **28**, 346.
[10] *J. Pharm. Chim.*, 1923, **28**, 209.
[11] *Proc. Acad. Sci. Amsterdam*, 1924, **27**, 132.
[12] *Russian Pet. and Oil Shale J.*, 1924, 620.

been attempted by Kabelac[13] by heating refined Borsylaw wax in a current of CO_2 at temperatures of 600°, 800° and 1000° C. At the lowest temperature 60 per cent. was decomposed to gas and 36 per cent. recovered as a light yellow oil of sp. gr. 0·770 without any aromatic content. At 800° C. 18 per cent. of a black mobile tar was obtained which contained benzene, toluene, naphthalene and anthracine, whilst at 1000° C. the wax was wholly decomposed to soot and asphalt.

Francis and his co-workers[14] have continued their studies on oxidation of paraffin wax. The velocity of oxidation under various conditions has been investigated, and it is concluded that oxidation takes place in stages with latest stages in between. It is thought that during the latest periods the formation of a catalyst occurs which promotes oxidation during the subsequent stage. When studying diseases promoted by contact with organic materials, Hoffman[15] painted mice with paraffin wax and found that malignant growths commenced after six months' application.

Oxidation Products of Petroleum.—Candea[16] heated Rumanian petrols (F.B.P. 150° C.) to 250° C. in glass tubes with oxygen in the presence of Fe_2O_3 as catalyst and obtained yields of aromatic hydrocarbons up to 6·4 per cent. The oxidation of vaseline by means of air has been studied by Tutunnikoff.[17] Vaseline was heated to 200° C. and upwards and air passed through at varying rates. The velocity of oxidation was found to increase with the rate of the air current, but not proportionally, and also to a greater degree with rise in temperature. Of metallic oxides as catalysts Mn_2O_3 gave the greatest oxidation, whilst with acetates manganese again supplied the highest yield and higher than that given by its oxide. Manganese acetate will give up to 90 per cent. oxidation by prolonging the treatment.

Chlorine Compounds of Petroleum.—Brooks[18] obtains chlorhydrins of distillation gases by means of absorbing the olefines in kerosene and treating the solution with aqueous hypochlorous acid.

Chlorine compounds of hydrocarbons are made by Tizard[19] by bringing the hydrocarbon into contact with a metallic halide having a dissociation pressure of at least 0·01 atmospheres at or below a temperature of 500° C. The nature of the resulting products varies with the time of contact, temperature and pressure employed.

[13] *11th Rept. Fuel Tech. Inst. Czec Poby Prague*, 1922, 86.
[14] *J. Chem. Soc.*, 1924, **125**, 381.
[15] *Deut. Med. Wochschr.*, 1923, **40**, 633.
[16] *Mon. Petr. Roumain*, 1924, **23**, 1925.
[17] *Z. angew. Chem.*, 1924, **37**, 300.
[18] *Chem. Met. Eng.*, 1924, **31**, 198.
[19] *J. Soc. Chem. Ind.*, 1924, **43**, B. 577.

Ultramicroscopical Researches on Asphalt.

By F. J. Nellensteyn, Ph.D., and A. J. P. van der Burgh.

The researches on asphalt, published by the senior author during the last year[1], were continued by ultramicroscopical examination of various kinds of asphalt.

Natural Asphalt from Trinidad.—A sample of the well-known "Trinidad refined" was dissolved into toluene. After separation of the non-soluble mineral matter, the dark-brown solution was examined with a cardioid ultramicroscope (from Nachet, Paris). Already without emersion, magnifying 160×, the ultramicroscopical particles are clearly visible, showing the Brownian movement. Magnifying 1000× and 2000× with emersion the image is very clear with particles of different colour. The intensity of the Brownian movement of the carbon particles depends in the first place on the viscosity of the medium. Opposite to aqueous sols, here the viscosity of the medium may be easily varied between very large limits, which may be of special interest for studying Einstein's laws for the Brownian movement. Taking lubricating oil as a medium the Brownian movement is very slow, while benzene, toluene and carbondisulphide-solutions of asphalt show an intense movement of the particles.

When the asphaltenes are extracted with gasoline we get an extract, which is not quite free from colloidal carbon, the separation being not quantitative. But when this extract is treated with acetone all the carbon is precipitated and the liquid extract, although of a dark red colour, is optically empty. The solutions of natural asphalt always contain some mineral substances such as $CaCO_3$. Those, too, may show a Brownian movement, as is the case with colloidal solutions of $CaCO_3$ in methanol.[2] The presence of inorganic matter, however, is not necessary to get an ultramicroscopical image.

Other Asphalts.—Italian rock-asphalt and Neuchatel asphalt (Val de Travers) show a similar ultramicroscopical image as Trinidad asphalt.

The colloid carbon in the natural asphalts is perhaps more uniform in size than the ultramicroscopical particles of artificial asphalts,

[1] *Chem. Weekblad*, 1924, **21**, 42, 533. *J. Inst. Petr. Tech.*, 1924, **10**, 311.
[2] Wo. Ostwald, *Kleines Praktikum der Kolloidchemie*, 1922, 10.

but the difference is very small. Generally spoken, the ultramicroscopical image of all asphalts is the same.

We examined the following artificial asphalts :—

Persian asphalt, obtained from a mixed base Persian oil by oxidation.

Mexican asphalt, obtained by distilling a heavy Mexican asphalt-base crude.

Borneo asphalt, obtained by distilling a heavy Borneo asphalt-base crude.

These natural and artificial asphalts represent asphalts of very different character, containing mineral substances (natural asphalt) and pure organic matter (artificial asphalt) almost free from sulphur (Borneo asphalt) and with a high percentage of sulphur (Trinidad and Mexican asphalt), Persian asphalt from a mixed-base crude and Borneo and Mexican asphalt from an asphalt-base crude. The Persian asphalt was obtained by oxidation, the Borneo and Mexican asphalt by distillation.

As already mentioned above the ultramicroscopical image of all these asphalts, notwithstanding their different character, was quite similar. Microphotos were taken from a Trinidad asphalt sol, with lubricating oil as solvent. Magnifying 1000× with cedar-oil emersion the ultramicrons were exposed 15 sec., 30 sec., 75 sec. and 150 sec. to the light of a 1000 h.c. lamp. In this viscous medium the Brownian movement of the carbon particles is so slow that the first photo showed them as points, the second as strips. The third and fourth photos showed irregular curls, caused by translatory and rotary movement of the ultramicrons.

Conclusions.—The two great classes of colloids, the lyophile and lyophobe sols show a marked difference in their behaviour to ultramicroscopical research. Generally the lyophobe ultramicrons are visible, the lyophile not. When in lyophobe sols the ultramicrons are strongly protected, they get many qualities of the lyophile sols, especially regarding the reversible solubility and being less sensible to flocking agents as the less protected sols, but towards the ultramicroscopic their character remains unchanged.

In asphalt solutions we have typical highly protected lyopholbe sols, showing reversibility by these protectors, while the ultramicroscopical image is due to the lyophobe carbon particles.

These results are in perfect accordance with the colloid carbon-theory of asphalt, published before.

In a recent paper Mr. Hackford made some objections against this theory[3], defending the old view of the complicated sulphur

[3] *J. Inst. Petr. Techn.*, 1924, **10**, 311.

and oxygen containing asphalt bodies. The difference between both views is not restricted to asphalt, it is the old opposition between "classical" and colloid chemistry. We have the same conflict in the case of the protected colloidal-gold solutions, which may show various colour and sensibility to electrolytes. The classical chemist explains these facts as caused by different compounds of gold and the protector f.i. SnO_2, whereas the colloid-chemist claims, that all these solutions are principally the same.

Notwithstanding the fact that gold, precipitated from these solutions, is never pure, elementary gold is regarded as the characteristic substance of these solutions. In Mr. Hackford's paper we find the common arguments of "classical" chemistry against a colloidchemical view on a problem. It is useless to repeat all the arguments pro and contra both views, but as a matter of fact asphalt offers many possibilities for colloidchemical researches. One of these is shown by the ultramicroscope. It indicates clearly the importance of the colloidchemical side of the asphalt problem.

The writers render thanks to Prof. Dr. H. I. Waterman for the interest he took in this work and for many a valuable advice.

Natural Gas.

By S. J. M. Auld, O.B.E., M.C., D.Sc.

The exploitation of natural gas has proceeded on known lines, and, apart from the prosecution of the survey of the natural gas resources of Canada by the Canadian Government, little of general interest has been recorded. R. T. Elsworthy[1] in a brochure on the subject points out that Canada now produces about twenty thousand million cubic feet of gas per annum, and stands second in the list of the world's producers. Ontario and Alberta are the two most prolific provinces. A short description of the Wainwright field of Alberta has been given by G. S. Hume.[2] The gas in this area is rich, analysis showing it to contain 2¼ per cent. of gasoline.

The continued search for helium in the Canadian natural gases has increased the possible sources of this important element, and although, so far, no gas has been discovered approaching in richness those of Texas, it is interesting to note that as much as 0·36 per cent. of helium has been obtained from certain Albertan natural gases.

[1] *Can. Dept. Mines Rept.*, 1924.
[2] *J. Inst. Petr. Techn.*, 1924, **10**, 83.

Natural Gasoline.—For the production of natural gasoline the absorption process continues to make headway against compression methods, absorption in oil at comparatively low pressures being now satisfactorily used for treating even the richer casing-head gases.

The activated charcoal adsorptive method appears to be finding its place in the industry chiefly for handling lean gases and the residue gases from oil absorption plants. R. C. Alden[3] gives a description of the design and operation of a plant working on such residue gases in the Mid-Continent field of the U.S.A. Using three adsorber vessels, each holding 18 tons of charcoal, and applying a pressure of 75 lb. on the vapours steamed from the adsorbent, it was found possible to treat 60,000,000 cu. ft. of gas per day. The gas received from oil absorption plant contained only 0·16 gallon of condensable hydrocarbons per 1000 cu. ft., but this was reduced to 0·012 gallon by the charcoal plant. Altogether the addition of the charcoal plant raised the efficiency of gasoline extraction from 69 to 79 per cent. during July and 87 per cent. during August.

In comparing the active charcoal and oil absorption processes (for benzol recovery) Steding[4] states that the charcoal plant costs 20–25 per cent. less than the oil absorption plant, and that its cost of operation is only one-third that of the latter, expressed in terms of the value of the benzol extracted. It should be realised in accepting these figures, however, that the gas treated was a lean one, containing only about 0·25 gallon benzol per 1000 cu. ft. In rich gases it is generally conceded that oil absorption is cheaper.

Removal of Hydrogen Sulphide.—Many natural gases contain hydrogen sulphide, and its removal may be necessary before the gas can be used either for domestic or industrial purposes. For small quantities of hydrogen sulphide the ordinary coal gasworks practice may be followed, but for larger amounts special methods must be used. The exceptional gas of the South Persian oilfields, which contains over 10 per cent. of sulphuretted hydrogen,[5] is best treated with milk of lime or by washing with sulphur dioxide solution, the latter being obtained from a portion of the sulphur formed during the reaction. For natural gas intended for domestic use L. Logan and G. G. Desy[6] have developed a process whereby the hydrogen sulphide is removed by means of sodium carbonate solution. The carbonate is reactivated by a current of air, which removes the hydrogen sulphide, the procedure being thus rendered continuous.

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[3] *Refiner*, 1924, **3**, 13.
[4] *Gas u. Wasserfach*, 1923, **66**, 457.
[5] *Cf. Auld, J. Inst. Petr. Techn.*, 1924, **10**, 46.
[6] *Natural Gas*, 1924, **5**, 12 *et seq.*

Literature.—An important feature of the work on natural gas during the past year is the appearance of a long-promised treatise on the recovery of gasoline from natural gas by Colonel George Burrell.[7] The book is by far the most complete and authoritative account of the subject published, and, being written by such an acknowledged leader in the domain of natural gas, is likely to become the standard work on gasoline extraction. As is fitting, the longest section is devoted to the oil absorption process, but the description of the charcoal process by its originator, the author, is powerful, and indicates the growing importance of this method. The chapter on gas measurement is the least impressive and might, with advantage, be extended in future editions.

Chemistry.

By F. B. Thole, D.Sc., F.I.C., F.C.S.

Study of the published researches on this aspect of petroleum during the year 1924 shows that attention is becoming more and more directed to the utilitarian side of the subject. The keynote of research is clearly, "What can be made from this material?" or "How can these products be improved from a commercial standpoint?"; and only to a very minor degree, "What is actually present in this raw material and what reactions will its components undergo under chemical stress?" It cannot be denied, however, that the former attitude creates a stimulus whose reaction automatically creates interest and progress in the latter aspects, whereas the converse would not necessarily hold good. Brooks,[1] in a paper which is full of suggestions for the research chemist with commercial instincts, surveys synthetic organic chemistry, viewing petroleum as the fundamental raw material and indicating how potentially valuable derivatives such as chlorhydrins, chloro-compounds, alcohols, nitrosochlorides, ketones, drying oils and resins can be prepared.

The main physical and chemical features of several important crude oils have been described during the year by Kewley[2] (Sarawak oil), Dunstan[3] (Persian oil), Wilson[4] (Burma and Assam oils),

[7] "The Recovery of Gasoline from Natural Gas." By G. A. Burrell. New York: The Chemical Catalog Co., Inc., 1925, pp. 599.

[1] *J. Ind. Eng. Chem.*, 1924, **16**, 185.
[2] *Journ. Inst. Petr. Techn.*, 1924, **10**, 42.
[3] *Ibid.*, 52.
[4] *Ibid.*, 227.

Kewley and Dunstan[5] (crude oils of the Empire) and Komatsu and Tanaka[6] (Japanese oils).

Ramsay[7] has drawn attention to the presence of nickel in nearly all oils, especially the more asphaltic ones, and considers it has played a catalytic part in the genesis of petroleum. Thomas[8] has collated analyses of the ashes from many petroleums, and discusses the presence of nickel and vanadium which are frequently present. He points out the weakness of the catalytic nickel theory, since nickel in nature does not occur free, but in combination with sulphur and arsenic, which destroy its catalytic powers. He also makes the interesting point that while phosphorus is present in petroleum well waters, vanadium can take the place of phosphorus in the economy of many plants.

Mabery[9] has summarised from his great experience the chief precautions to be taken in the analytical combustion of petroleum. He finds it essential to use a dual oxygen supply (one behind and the other in front of the boat), and to work at the highest available temperature, using a mixture of granular and powdered copper oxide. Catalysts had no markedly beneficial influence.

Cadman[10] has published drawings and details of a modification of Tizard-Marshall's apparatus for determining the vapour pressure of petroleum and its distillates at various temperatures. Using the apparatus described no selective evaporation occurs to alter the composition of the liquid phase, and this simple and accurate method will be of great practical use.

Ashworth[11] has obtained an interesting mathematical relationship between the vapour pressures and boiling points of the simpler hydrocarbons.

Zelinsky[12] has isolated hepta-, octa-, nona- and decanaphthenic acids (all mixtures of isomerides) from Baku petroleum, and converted them into the corresponding hydrocarbons. These were all similar to cyclohexane in chemical stability but contained no cyclohexane ring. The soaps from naphthenic acids have a characteristic odour, which can be removed by extraction with petrol or by heating the acids with formaldehyde and distilling from the resinous by product.[13]

Nellensteyn[14] aroused much interest and controversy by the suggestion that asphalt is really colloidal carbon impregnated with

[5] *Journ. Inst. Petr. Tech.*, 1924, **10**, 486.
[6] Mem. Kyoto Univ., 1924, **7**, 77, 143.
[7] *Journ. Inst. Petr. Techn.*, 1924, **10**, 87.
[8] *Ibid.*, 216.
[9] *J. Ind. Eng. Chem.*, 1924, **16**, 911.
[10] *Journ. Inst. Petr. Techn.*, 1924, **10**, 947.
[11] *Ibid.*, 787.
[12] *Ber.*, 1924, **57**, 42.
[13] *Z. angew. Chem.*, 1924, **37**, 637.
[14] *Journ. Inst. Petr. Techn.*, 1924, **10**, 311.

adsorbed oil which cannot be removed, and he claims to have synthesised asphalts from colloidally dispersed carbon and distillate hydrocarbons. Critics have pointed out that he does not define "asphalt," and that he ignores the important part played by oxygen and sulphur in both natural and artificial asphaltic mixtures.

Hessel[14a] has repeated and confirmed much of Tallaz and Peter's researches on the assimilation of hydrocarbons by bacteria. Some species will oxidise benzene and toluene through the stage of phenols to carbon dioxide. Paraffins are somewhat readily attacked, but naphthenes are highly resistant, so that a separation of the two types of hydrocarbons can be effected by this means.

As is natural in an age of "cracking" the thermal decomposition of hydrocarbons has received further study. Gault and Hessel[15] show that with hexadecane decomposition starts at 390°, terminal decomposition predominating. Thus at 470° C. the chief products are methane, and the C_{15} olefine and ethylene plus the C_{14} paraffin. At higher temperatures naphthenes and above 685° C. aromatic hydrocarbons are produced. They make the interesting and unusual observation that acetylene is formed at 615° C. Hexadecene show similar terminal decomposition.

Zelinsky[16] records that cyclohexene at 165° C. in contact with palladium black undergoes simultaneous hydrogenation and dehydrogenation, cyclohexane and benzene being formed; the reaction is irreversible.

Lind and Bardwell[17] make the interesting observation that ethane under the influence of α radiation yields hydrogen and a liquid hydrogen (possibly octane).

Dunstan and Pitkethly[18] give a full and valuable summary of the chief features of all the principal cracking processes, including that of Bergius, in which hydrogenation is alleged to be induced. An account is also given of the composition and refining of typical cracked spirits.

There is as yet no satisfactory method for the estimation of the olefine and naphthene content of benzine, and a number of attempts to devise an accurate method have failed. Ormandy and Craven[19] found that the olefines in petrol, when boiled for four hours with formalin and hydrochloric acid, were converted into resins, but the yield of resin was much smaller than the olefine content as indicated by the bromine number.

[14a] *Mat. Grasses*, 1924, 6936.
[15] *Ann. Chim.*, 1924, **10**, 319; *Comptes rend.*, 1924, 171.
[16] *Ber.*, 1924, **57**, 2055.
[17] *Science*, 1924, **60**, 364.
[18] *Journ. Inst. Petr. Techn.*, 1924, **10**, 728.
[19] *Ibid.*, 99.

Danaila, Andrei and Melinescu,[20] however, state that olefine are completely removed without affecting other hydrocarbons by the action of ozonised oxygen at −10° C. Ormandy and Craven[21] have compared the naphthene content as indicated by the aniline point, specific gravity and refractivity methods, and find considerable discrepancy; the nearest approximation is probably attained by averaging the three discrepant results.

Oxidation and reduction of hydrocarbons is still a fertile field for research. Tropsel and Roelen[22] have studied further the oxidation of methane to formaldehyde. The highest yield (6 per cent.) was obtained by passing the methane-air mixture through a hot quartz tube at 20 metres per second. The higher the temperature the greater the absolute yield, but the smaller the yield per unit of methane.

Francis[23] has continued his interesting and important work on the oxidation of Scotch Shale Wax. This is essentially a mixture of seven paraffin hydrocarbons, and an oxidation by air at 100° C., a long induction period with no apparent action, is followed by a smooth and rapid exothermic oxidation. This latest period may be due to the slow destruction of an inhibiting catalyst, but more probably an active catalyst is slowly formed. Waterman and Kortlandt[24] have studied the hydrogenating effect at a high temperature of carbon monoxide and water. They find that wax and its decomposition products are unaffected, but brown coal shows distinct signs of hydrogenation.

Shatwell[25] and Mott[26] have done further work on the cracking of gas oil under high pressures in contact with hydrogen and inert gases. Both agree that hydrogenation does occur, but it appears to be confined almost entirely to the gaseous products. The liquid products are either identical with Mott or slightly less unsaturated (Shatwell) than those formed under identical conditions in an inert atmosphere.

The oxidation of boiling hexane by ozone has been shown to give all the aldehydes from formic to hexoic, acetaldehyde predominating.[27]

Blair, Ledbury and Wheeler[28] made the interesting record that n-hexane on bromination yields *p*-dibromobenzene; cyclohexane is presumably the intermediate cyclic compound.

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[20] *Chem. Abstr.*, 1924, **18**, 3710.
[21] *Journ. Inst. Petr. Techn.*, 1924, **10**, 101.
[22] *Brennstoff-Chemie*, 1924, **5**, 37.
[23] *J. Chem. Soc.*, 1924, **125**, 387.
[24] *Rec. Trav. Chim.*, 1924, 249.
[25] *Journ. Inst. Petr. Techn.*, 1924, **10**, 903.
[26] *Ibid.*, 911.
[27] *J. Soc. Chem. Ind.*, 1924, **43**, 287.
[28] *Ibid.*, 289.

Ormandy and Craven,[29] using heptane as stock material, have tried to correlate the action of anti-detonating chemicals with the spontaneous ignition temperature, but find that whereas amines give a marked increase in this temperature, the lead alkyls give an equally large diminution. It is of interest to note that iron carbonyl in 0·17 per cent solution has been patented by the Bodische[30] as an anti-detonating agent.

Methyl alcohol as a synthetic motor fuel has been studied by Fischer and Tropod,[31] who make it by passing water gas over an iron-potash catalyst at 410° C. and 75 atmospheres; formaldehyde is the intermediate compound and is decomposed by the alkali. Patart,[32] by passing carbon monoxide (1 vol.) and hydrogen (2 vols.) over zinc oxide at 400° C. and 150 to 250 atmospheres with a cooling zone at 20° C. in the system obtains practically pure aqueous methyl alcohol.

A great deal of interesting research on the sulphur compounds of petroleum has been published during the year.

Wendt and Diggs[33] have examined in detail the chemistry of the "Doctor Test," and have proved that only hydrogen sulphide and mercaptans give a positive reaction; sulphur, sulphides and disulphides are inert. Mercaptans give yellow lead mercaptides, which partly remain dissolved in the oil. By the addition of sulphur to precipitate these lead sulphide is precipitated and alkyl disulphides remain in the oil. These are inert to sodium plumbite and less odorous than the mercaptans, so that an oil treated in this way (the usual American practice), though sweetened (that is not so odorous and non-reactive to plumbite), contains at least as much sulphur as it did originally. Elemental sulphur on standing oxidises mercaptans to disulphides, a fact which explains the often-noted difference between a fresh and a still distillate.

Brooks[34] mentions that spirits containing olefines often give a yellow colour with plumbite solution though free from mercaptans; the colour is due to the presence of peroxides formed by atmospheric oxidation of the olefines. Dunstan[35] has described in exact detail the hypochlorite process which is now so widely used for desulphurisation of petroleum distillates.

Waterman and Heimel[36] have examined the action of sodium hypochlorite on a variety of individual sulphur compounds, but their choice fell on many which are not present in petroleum, so

[29] *Journ. Inst. Petr. Techn.*, 1924, **10**, 335.
[30] E.P. 226,731, 1924.
[31] *Brennstoff-Chemie*, 1924, **5**, 201, 217.
[32] *Comptes rend.*, 1924, **178**, 1330.
[33] *J. Ind. Eng. Chem.*, 1924, **16**, 1113.
[34] *Journ. Inst. Petr. Techn.*, 1924, **10**, 588.
[35] *Ibid.*, 201.
[36] *Ibid.*, 812.

that the experiments are not of direct interest to the petroleum chemist.

Wood, Lowy and Faragher[37] have published a long and important summary of the action of the chief petroleum refining agents on each of the chief types of sulphur compounds (sulphur, hydrogen sulphide, marcaptans, thio ethers, disulphides and thiophen).

Sulphuric acid oxidises hydrogen sulphide to sulphur and mercaptans to desulphides, dissolves sulphides and thiophen and (partly) disulphides. The action of sodium plumbite has been mentioned above.

Copper oxide removes hydrogen sulphide and (partly) mercaptans. Sulphur, sulphides and disulphides are unattacked, and the copper mercaptides are apt to decompose to sulphides and disulphides.

Sodium hypochlorite is said to convert mercaptans to disulphides, hydrogen sulphide to sulphur, and to be inert to sulphides and disulphides. (A recent publication, however, controverts some of these statements.)

Aluminium chloride in cold gives addition compounds with mercaptans, sulphides and disulphides which, on heating, decompose to hydrogen sulphide and mercaptans.

Dunstan, Thole and Remfry[38] have published a long and detailed account of the use of bauxite as an adsorptive agent for the removal of sulphur compounds, colour and other undesirable constituents from petroleum distillates, and for polymerising reactive compounds such as olefine hydrocarbons and certain thio-compounds. They show that the Freundlich Law of Adsorption is followed, and the influence of each of the many variables, such as size of grain, temperature of roasting, temperature and pressure of filtration, shape of the filter bed and time of filtration on the efficiency of the operation, is described. It is demonstrated that the chemical composition of the material has no bearing on its efficiency, which is purely dependent on the physical structure of the roasted mineral, and an ingenious device is described for determining, by measurement of the heat of wetting, the surface activity on which the refining action depends.

A very informative account of the preparation and use of clays for refining has been compiled by von Bibra.[39]

The conditions influencing the sludging of transformer oils have engaged the attention of Heyden and Typke,[40] who find that if the oil is heated in contact with air and various metals, the most severe sludging occurs with copper and its alloys; in the absence of air no sludge was produced. If the oil is heated in contact

[37] *J. Ind. Eng. Chem.*, 1924, **16**, 1116.
[38] *J. Soc. Chem. Ind.*, 1924, **43**, 180.
[39] *Refiner*, 1924, **3**, (7) 15.
[40] *Petroleum*, 1924, 857, 903, 953 and 1128; *Petr. Zeit.*, 1924, **20**, 320.

with air and various metallic soaps, very high sludges were formed with copper and iron soaps, a lesser amount with magnesium and aluminium soaps, and none with sodium or potassium soaps.

A publication of great interest comes from the Swedish General Electric Company,[41] who have compared the sludging properties of a transformer oil over long periods under the actual working conditions of high electric stress with parallel tests in the absence of an electric field. In the former case the sludge and acidity were 150 per cent. higher than in the latter case.

The nature of the organic matter in shale has received attention from several investigators. McKinney[42] found that New Brunswick shale, which gives 30 gallons of oil per ton, on extraction with solvents yields 1·5 per cent. with alcohol, 2·6 per cent. with acetone and 6·9 per cent. with acetic acid. The acetone extract consists of 10 per cent. asphaltenes, 5 per cent. resins and 85 per cent. hydrocarbons; the latter, after removal of the two former by filtration through fuller's earth, prove to be saturated compounds. The kerogen of this shale on digestion with nitric acid is converted into humins.

Blackburn[43] has studied the effect of gentle depolymerisation of kerogen by restricted heating, and has isolated various hydrocarbons, including heptocosane from the product.

Shatwell, Nash and Graham[44] have examined very thoroughly the amount and nature of the oil obtainable from a much-boomed Somerset shale deposit. Their results show that the yield is poor (5-10 gallons per ton), the sulphur content high and the refining very difficult.

Nash and Shatwell[45] have continued their experiments on the Berginisation of coal, using separately the various constituents—clarain, fusain, etc. They find that when coal is heated to 400-430° with hydrogen at 100 atmospheres very little action occurs, but if the coal is suspended in a high-boiling mineral oil or in phenol liquefaction of up to 50 per cent. of the coal, substance occurs. It is shown that hydrogen precedes the reliquefaction, and that when the hydrogen is replaced by nitrogen very little liquid product is obtained. Clarain and durain are much more readily attacked than fusain.

The liquid products are black viscous liquids, and chemists will look forward with keen interest to the publication of a more detailed examination of the chemical nature of these oils and their components.

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[41] *Asea J.*, 1924, 123.
[42] *J. Amer. Chem. Soc.*, 1924, **46**, 968.
[43] *Col. School of Mines*, 1924, **19**, No. 2.
[44] *Journ. Inst. Petr. Techn.*, 1924, **10**, 872.
[45] *Journ. Inst. Petr. Techn.*, 1924, **10**, 865.

Analysis and Testing of Petroleum.

By S. Bowman, F.I.C.

A review of the literature issued during 1924 reveals the fact that little or nothing has been done in the way of modifying or amending those methods which have become standardised in this country by the Institution and in America by the A.S.T.M. While this general adoption must be gratifying to these bodies, standardisation should not be allowed to discourage investigation of new apparatus and methods.

Apart from the general examination of petroleum products considerable progress has been made in the investigation of the behaviour of certain groups of hydrocarbons when used as fuels, for internal-combustion engines, and this in turn will compel analysts to supplement the usual physical characteristics with more detailed information as to the composition of these facts.

As an example of this, the modern high-speed automobile engine calls for a spirit that in very few instances can be a straight cut from the crude, and it is possible that the ideal motor spirit of the future will be a blend of several types of hydrocarbons in definite proportions. This may be looking a long way ahead, but much work remains to be accomplished before the proximate analysis of a motor spirit can be stated with precision.

Ormandy and Craven[1] show that three methods can be employed for the determination of napthenes in a spirit which has been previously treated with 98 per cent. sulphuric acid to remove all except paraffin and cyclo-paraffin hydrocarbons. The first of these methods is based on the work of Tizard and Marshall, and depends on the fact that the analine point of a cyclo-paraffin is lower than that of a paraffin by an amount which is a function of the boiling-point. The average figure of 0·3° C. per 1 per cent. is taken for the total napthene content; the second method utilises the fact that the average nap-thene has a gravity of 0·1 higher than that of a paraffin of similar boiling point. The gravity-boiling-point curves of both these series is nearly a straight line, and the difference affords data for the calculation; in the third method the difference in specific refractivity is similarly employed. Spirits examined by the three methods show some discrepancies, and the authors are of the opinion that the mean is probably nearest the truth.

A recent paper by Hoyte[2] gives an alternative method for the

[1] *J. Inst. Petr. Techn.*, 1924, **10**, 101.
[2] *Ibid.*, 1925, **11**, 76.

determination of aromatics, the difference in refractive indices being utilised as a data for calculation. This method has, in common with the specific gravity and C.S.T. methods, the objection that the effect of other constituents removed by the acid is unknown.

Miskin[3] has examined the iodine values of spirits obtained from different types of cracking processes, and confirms the observations of other workers that this value is influenced by so many factors that little or no interpretation can be obtained from the results. Similarly the meaning of absorption by sulphuric acid of various concentrations is very obscure.

Ormandy and Craven[4] have examined the possibility of determining unsaturates by means of formaldehyde. On refluxing spirit with this reagent in the presence of an electrolyte such as hydrochloric acid, they obtained a percentage of resin which was roughly proportional to the bromine member of the spirit. The detection of dopes in spirit is often a matter of considerable difficulty, but Birch[5] describes a method of estimating lead tetra ethyl by digestion with concentrated sulphuric acid in a Kjeldahl flask. The lead is precipitated as lead sulphate and estimated in the usual manner.

Ormandy[6] prefers to treat the spirit with chlorine, filtering off the precipitated lead compound and then digesting this with hydrochloric acid. Sodium acetate is added and the lead estimated as chromate.

R. Jungkunz[7] uses ammoniacal nickel cyanurate for the detection of benzol, pyridine, thiophene and furfuran. This reagent gives a precipitate which is quantitative and does not react with the higher aromatics or turpentine.

B. T. Brooks[8] shows that the sodium plumbite test may give misleading results owing to the presence of organic perioxides formed from cracked spirit, etc. These bodies precipitate lead peroxide, which is similar in appearance to the colour produced from sulphur compounds present in unrefined distillate.

E. M. Johansen[9] describes a method for measuring the interfacial tension between petroleum products and water, and shows how minute traces of organic acids lower this value and can thus be detected. The drop method is used, the water being allowed to flow through the oil in the case of transparent samples and the oil through the water with non-transparent oils.

Methods of measuring the vapour pressure of petrol are de-

[3] *Journ. Inst. Petr. Tech.*, 1924, **10**, 297.
[4] *Ibid.*, 1924, **10**, 99.
[5] *Ibid.*, 1924, **10**, 816.
[6] *Ibid.*, 1924, **10**, 954.
[7] *Chem. Zeit.*, 1924, **48**, 455.
[8] *Ind. Eng. Chem.*, 1924, **16**, 588.
[9] *Ibid.*, 1924, **16**, 132.

scribed by F. B. Rhodes and E. B. McConnell[10] and also by Cadman.[11] The latter uses a modification of Tizard and Marshall's apparatus, a stirring device being fitted to give the maximum pressure in the shortest time. It is shown that there is no correlation between the initial boiling-point (I.B.P.) as ordinarily defined.

Ashworth[12] discusses the subject of vapour tensions from a theoretical standpoint.

Ormandy and Craven[13] advocate the use of thermocouple instead of the mercury thermometer used in Engler distillations on account of the considerable lag of the latter in the initial stages of the distillation. This may be as much as 15°, but after the first 1 per cent. drops quickly to 1° or less.

Lomax and Bevan[14] describe a modification of the lamp method for the estimation of sulphur in volatile hydrocarbons with particular reference to benzol. The main feature of the apparatus consists of a helix of platinum wire supported in the flame to promote complete combustion of the volatile sulphur compounds.

L. H. Milligan[15] has determined the solubility of hexane, heptane and benzene in water, and finds that 0·0014, 0·0007 and 0·07 volumes respectively are dissolved in 100 parts of water at 25° C.

S. E. Campbell[16] determines the gasoline content of a crude oil by distilling 1000 c.c. over a 14 in. column at a rate of 10 c.c per min. up to 437° F.

C. F. Mabery[17] describes the apparatus he uses for combustions. Oxygen is admitted in front of and behind the boat, enabling the operation to be completed in less than two hours.

A semi-micro method for the determination of carbon has been worked out by Polonowski.[18] Barium hydroxide solution is used to absorb the carbon dioxide, the resulting barium carbonate being collected out of contact with air, washed, dried and weighed. An ordinary balance is employed, and determinations can be made on less than 50 m.g. of material.

Cyclohexane has been proposed as a precipitant for asphalt determinations, and M. Jakes[19] shows that a large proportion of the asphalt obtained by petroleum ether is soluble in cyclohexane. He observes that the asphalt precipitated by cyclohexane is therefore more useful for the detection of aromatics

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[10] *Ind. Eng. Chem.*, 1923, **15**, 1273.
[11] *J. Inst. Petr. Techn.*, 1924, **10**, 947.
[12] *Ibid.*, 1924, **10**, 787
[13] *Ibid.*, 1924, **16**, 342.
[14] *Ibid.*, 1924, **10**, 914.
[15] *J. Phys. Chem.*, 1924, **28**, 494.
[16] *Oil Age*, 1924, **21**, 16.
[17] *Ind. Eng. Chem.*, 1924, **16**, 911.
[18] *Bull. Soc. Chem.*, 1924, **35**, 414.
[19] *Chem. Abstr.*, 1924, **18**, 1047.

according to Holde's method than that obtained by petroleum ether, as the latter may give a brown colour if napthenes be present.

Several modifications of the sludge test for transformer oils are put forward. Knutson[20] heats 20 gms. of the oil at 200° C. for 10 hours, dilutes with 200 c.c. benzine, and after standing overnight filters through an alundum crucible. After washing, the precipitate is dried for 10 mins. at 100° C., and then broken up and digested with more benzine, dried and weighed.

Marcusson[21] treats a mixture of 5 gns. oil and 5 c.c. c.m.c. sulphuric acid with 2·5 c.c. of 40 per cent. formalin, and refluxing for 1 hr., 50 c.c. of water is added, and after cooling, ammonium hydrate added, and the precipitate collected and extracted with benzine to remove any oil and weighed.

The British Electric and Allied Industries Research Association[22] in their report consider the sludging test to be the most important, and point out that the use of oxygen instead of air renders the results uncertain. The presence of copper and its alloys, lead, cobalt and manganese increase the amount of sludge formed.

W. H. Nuttal[23] describes a physical test for determining the sludging tendencies of an oil, based on the fact that unsaturated hydrocarbons have a much greater affinity for water than saturated hydrocarbons. As a rough test a drop of oil applied to the surface of water will indicate its sludging properties. Actual determinations are made with a special pipette, using the drop method T 40 per cent. sulphuric acid instead of water. This accentuates the difference in surface tension, and the results obtained are in all cases confirmed by actual sludge determination.

R. E. Wilson and R. E. Wilkin[24] describe a method of determining the amount of oil in wax by extraction with ethylene dichloride and then taking the index of refraction.

K. Fricker[25] differentiates between setting time and melting-point of a wax, the former being important for candle manufacture. This is ascertained by melting 100 gms. and when nearly set applying a square plunger loaded with 1 k.g. until no impression is visible, the time from pouring being noted. This varies from 50 mins. for high melting-point to 80 mins. for low melting wax. In the analysis of gases obtained from cracking operations difficulty is often experienced in getting a constant absorption with bromine or fuming sulphuric acid.

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[20] *Chem. Abstr.*, 1923, **17**, 3784.
[21] *Ibid.*, 1924, **18**, 748.
[22] *J. Inst. Elect. Eng.*, 1923, **61**, 661.
[23] *World Power*, 1924, **2**, 92.
[24] *Ind. Eng. Chem.*, 1924, **16**, 9.
[25] *Chem. Zeit.*, 1924, **48**, 624.

H. Suida and A. Wiseley[26] recommend bromine water of 0·04 per cent. concentration for this purpose.

B. Joachim[27] gives a method which is claimed to be quicker and more accurate than the A.S.T.M. method for the analysis of greases.

Dobson[28] describes an aspirator for collecting gases at atmospheric pressure.

D. Holde and S. Weill[29] use aniline for the quantitative separation of tar oil from mineral oil. The former are easily soluble in this reagent, which has the advantage of being less poisonous than methyl sulphate.

Mabery[30] has attempted the separation of the heavier fractions of petroleum present in lubricants by distillation of the oil to 300° C. under a pressure of 30 mm. and then removing the wax in the residue by means of alcohol ether. The wax free residue was then further separated by means of fractional solubility in the same solvent.

A. Holmes[31] describes a method of examination to determine the suitability of an oil for gas manufacture.

Cracking.

By R. Pitkethly and A. E. Dunstan, D.Sc., F.I.C., F.C.S.

From experimental and industrial points of view, there are no signs of abatement of interest in cracking and cracking processes. Formerly cracking on a commercial scale has been mainly conducted in the United States of America, but there is evidence of world-wide recognition that the cracking plant is an essential part of the modern refinery. Refiners in general are awake to the fact that the cracking plant should be considered as a normal part of their equipment, which can be utilised for balancing the output of marketable products, as it presents a solution to the problem of the disposal of heavy by-products which either congest the refinery or yield little or no return.

A factor which is often overlooked in considering the future gasoline production in relation to crude oil supplies lies in the development of cracking, and it is possible that a considerable reduction in crude oil output can come without reduction in the

[26] *A. Anal. Chem.*, 1924, **64**, 143.
[27] *Ind. Eng. Chem.*, 1924, **16**, 725.
[28] *J. Chem. Soc.*, 1924, **125**, 1968.
[29] *Chem. Abs.*, 1923, **17**, 3771.
[30] *Ind. Eng. Chem.*, 1923, **15**, 1233.
[31] *Ibid.*, 1924, **16**, 258.

motor fuel supply.[1] The era of the improvement and further development of cracking processes is not yet at an end, and the application of pyrolysis to oil other than petroleum is being actively prosecuted.

T. A. Boyd,[2] in his contribution on the subject, states that last year 35 per cent. of all refineries in the United States were shut down on May 1st, but out of the total only 10 per cent. of those fitted with cracking plant were not operating, whilst the total rated capacity of the plants equipped for cracking which were shut down represented only 2 per cent. of the capacity of all the refineries which do cracking.

These figures are instructive, and point to the advantage of the cracking installation as a part of the ordinary refinery equipment.

There are, at present, about 40 different cracking processes in use, but many of them are worked on the same principle and differ only in constructional details or methods of operation.

It is noticeable that the most successful processes have generally adopted the method of imparting the necessary heat to the oil, in pipe stills, thus keeping the main body of oil, under treatment, away from the source of heat. Heating in tubes not only increases the safety factor, but also minimises the formation of coke in the heating zone, where it would do most harm and cause premature stoppage. The increased velocity of the oil also reduces the liability to deposit coke in that part of the plant, and carries it forward into the reaction chamber provided for the purpose.

Cracking processes are being improved and yields of motor fuel gradually increased, but there is the general feeling that more fundamental research on petroleum and its products is required. It seems certain, also, that, with gradually accumulating data on the factors involved in the production of motor fuel, great improvements will be made over the best methods of to-day. Past progress has been more physical than chemical. Engineering problems have been the most urgent, for the simple reason that the conditions of heat and pressure of a modern cracking plant were an impossible proposition ten years ago, and engineers had to become educated in order to devise materials and methods that would operate under new and strenuous conditions.

Brooks[3] and Bacon[4] have stated that the petroleum industry owes its strength to skilful management and good engineering, and that no industry of like magnitude has such a dearth of fundamental chemical knowledge on which to base its operations.

G. A. Burrell[5] states that the best efforts of hundreds of tech-

[1] *Nat. Petr. News* **16**, 34-51.
[2] *Ind. and Eng. Chem.* **16**, 100-4.
[3] *Ind. and Eng. Chem.* **16**, 185.
[4] *Ibid.* **15**, 888.
[5] *Ref. and Nat. Gas. Mfr.* **4**, 3.

nologists and an amount of money ranging from 50 to 100 million dollars have been expended in the development of cracking processes, but that the chemical side of the art is weak. It would be interesting to know how much of this effort and money has been spent on the engineering development of the processes involved and how much went towards the cost of chemical research.

Very little is known about the chemical composition of the initial charging stocks which are used in cracking; and about as much is known of the final products, while the intermediate reactions are only guessed at. It is known that the heavier hydrocarbons break down into simpler compounds, but less is known about the polymerisation of the intermediate compounds into substances of higher molecular weight. Gaseous compounds are invariably produced in cracking, and these have been examined in some detail. From these gases various substances (*e.g.*, propanol) have been synthesised, but the liquid products of cracking still remain a field for research. In the process itself, the conditions under which cracking is accomplished have a profound effect on the constitution of the products, and in this respect much work can be done to standardise methods in order to produce certain results. Pressure has a definite effect, small temperature differences have a great effect, so that, for example, a rise of 10° C. will approximately double the quantity of spirit made, within limits; polymerisation invariably takes place, whereas if catalysts are used pyrolysis is modified profoundly. At the moment, however, efforts have been concentrated on the production of motor spirit, and with that object improvements in existing plant and new inventions have been made.

In the Dubb's plant,[6] one of the improvements is an adaptation of the Lientz principle to the furnace, which previously was working inefficiently. Another advance consists in the development of hot oil pumps in order to recycle the reflux oil from the dephlegmator. This oil must be handled at a temperature of 450° C., and previously the action of gravity was relied on to recycle the oil.

The improvement in the furnace, according to the operators, has resulted in great fuel economy, and consists in, firstly, utilising waste heat to preheat the air necessary for the combustion of the fuel; and, secondly, circulating part of the flue gases back into the combustion chamber in order to prevent loss through incomplete combustion. The effect of this improvement is said to reduce fuel consumption from 6·7 per cent. to 1·7 per cent.

The second improvement, the hot oil pump, gives a positive feed. When operating by gravity, the recycling was slow and uncertain, but it was a matter of difficulty to find a pump which

[6] *Nat. Petr. News* 17, 7.

could deal with extremely hot oil. Two pumps have been designed; the first is guaranteed to work at a temperature of 540° C., and the other operates on the principle of placing a plug of cold oil between the valves and the pump. In this way the packing of the pump glands is not destroyed, and remain in contact with cold oil at all times. The throughput of the Dubb's plant has also been increased from 500 to 750 barrels per day.

In the Carlton-Ellis plant, improvements make the plant a combination of cracking and ordinary stills. It is capable of running crude, topped oil or other stocks in various ways. Heat is transmitted to cracking coils, and the oil passes into upright "soaking drums" or reaction chambers, from which it is expanded into vapourising stills. The working pressure is 350 lb. per square inch.

The Cross process has been improved by the addition of specially designed and highly efficient bubble towers, which render the plant capable of delivering end point gasoline without redistillation.

The Jenkins process[7] has had a long period of development. The original furnace has been re-designed, and the revolving fan for circulating the oil has been increased in size, a 28 in. tug propeller being now used, in place of the small and futile affair originally used.

Development of the Auld, Dunstan and Herring process on an industrial scale proceeds satisfactorily. The construction of an automatic valve, which works at high temperature and maintains the pressure constant throughout the time of running without attention, is a detail worthy of notice.

George A. Burrell[8] is of the opinion that the Dubbs, Cross, Ellis, Holmes-Manley, and the Auld Dunstan and Herring processes are representative of the cracking art to-day.

New processes of many types have been patented, such as those of J. H. Reddrick,[9] C. M. Page,[10] J. H. Adams[11] and O. P. Amend, who have brought out processes for the heating or cracking of oil by electrical means.

I. M. Davidson and G. P. Lewis[12] use a stream of molten tin. Two concentric tubes form the cracking zone. Molten tin flows down the centre tube and up the annular space between the tubes. The oil is injected at the bottom of the outer tube into the upward flowing metal, and the process operates at about 400° C and 600 lb. pressure.

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[7] *Nat. Petr. News* **17**, 9-72.
[8] *Ref. and Nat. Gas Mfr.* **4**, 3-23.
[9] U.S.P. 1,496,742, *Journ. Inst. Petr. Techn.* **10**, 254A.
[10] U.S.P. 1,494,125, *Ibid.* **10**, 254A.
[11] U.S.P. 1,506,877 **8**.
[12] B.P. 220,732.

McAfee[13] passes oil vapours counter current to vapours of aluminium chloride in a heated zone with progressively increasing temperature in the direction of the oil flow.

Blumner[14] treats oil with molten lead, which is heated to the required temperature outside the autoclave and introduced in direct contact with the oil. In this manner no over-heating can take place.

Harold Ridgeway[15] claims that the entire mass, of the oil to be treated, is converted into light products by passing hot hydrogen-containing gases and steam upwards against a descending stream of oil, which is caused to form films of oil in the apparatus specially designed for the purpose. In this way the oil is subjected to ever increasing temperature and the gases to ever decreasing temperature, as heat is constantly transferred to the oil through contact. It is claimed that the process produces molecular instability of the hydrocarbons under treatment and hydrogenation takes place, thus lowering the boiling points of the hydrocarbons, with substantially complete conversion at a temperature and pressure insufficient to crack the oil.

A method is submitted for determining the proper co-efficients of temperature and pressure requirements, depending on the analysis of the oil to be treated.

The problem of refining cracked gasoline is discussed by J. C. Morrell,[16] and some methods of treatment for products obtained from types of oils are described. The high sulphur and asphaltic character of Mexican and South American oils make the distillates particularly difficult to refine, but the methods outlined are claimed to give such marketable products. These methods are variations of sulphuric acid, soda and doctor treatments.

F. G. P. Remfry[17] treats cracked spirit by passing it upwards through a heated filtering medium such as bauxite, fuller's earth, floridine or activated char. The unsaturated compounds are polymerised, and on passing the liquid through a cold filtering medium such as bauxite they are removed.

Thomas T. Gray[18] presents a new process which is a step towards complete refining between the still and storage tank. The process has created considerable interest, and is based on the polymerising action of fuller's earth on cracked spirit in the vapour phase. In the treatment of cracked spirit sulphuric acid is the refining agent generally used, although it is known that more components than

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[13] U.S.P. 1,501,104.
[14] *Petr. Times* **13**, 314.
[15] E.P. 202,317, *Journ. Inst. Petr. Techn.* **11**, 23A.
[16] *Chem. and Met. Eng.* **30**, 785. *Journ. Inst. Petr. Techn.* **10**, 169A.
[17] B.P. 212,500.
[18] *Nat. Petr. News* **17**, 6.

necessary are removed by its action. It also has a polymerising action which raises the end point of the refined spirit, thus increasing the loss. Certain compounds are also formed which are not removed by soda treatment, but decompose on redistillation and set free SO_2 which has a corrosive action on stills and other plant. These objections have, on more than one occasion, been discussed by B. T. Brooks and his collaborators.

It is claimed for the Gray process that the losses are only a fraction of the losses due to sulphuric acid, and that satisfactory gasoline and kerosene are produced in an inexpensive and simple manner. Paraffins, naphthenes, olefins and aromatic compounds are apparently unacted on, whilst only the diolefins or gum-forming substances are removed.

Only one commercial unit[19] of the process has, so far, been in use, and the refiners state that the process does produce a water white product at a cost cheaper than that of acid treating and removes the objectionable gum-forming compounds, but it does not eliminate the necessity for redistillation, nor does it sweeten the spirit since sulphur compounds are not attacked or removed.

The plant may be directly connected to the cracking still to treat the vapour before condensation takes place. As much as 1300 barrels of pressure distillate have been treated per ton of earth, and the losses vary from ·3 to 1·5 per cent., according to the quality of the cracked distillate.

Research chemists[20] have been busy on many projects for the manufacture of new products from cracking plant gases. Isopropyl, amyl, butyl and other alcohols have been made, and reduction of the cost of manufacture is all that is required to make their production successful commercially.

The cracking of oil has been largely used as a means of keeping up with the increasing demand for motor fuel, and in the development of processes efforts have been made to restrict the production of gas. It is possible, however, that, while maintaining the output of motor spirit, increased production of cracked gases will become desirable,[21] as the possibility of converting them into products, which are at present available only in limited quantity, becomes practicable.

There are other problems in connection with cracking which challenge the research chemist, such as the investigation of the gum-forming diolefin compounds, which may yet be converted into useful materials but are at present merely a nuisance to the refiner.

Corrosion of plant and the production of metals or alloys for the construction of cracking plant also require attention.

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[19] *Ref. and Nat. Gas. Mfr.* 3, 12-13.
[20] *Nat. Petr. News* 17, 15.
[21] U.S.P. 1, 520, 804.

Nellensteyn,[22] in his work on the constitution of asphalt and the formation of colloidal carbon, has opened up another section of the subject which may have a direct bearing on the problem of the development of a cracking process which can be carried on continuously for an indefinite period. This question is exercising the minds of many petroleum chemists at the moment, for the inevitable choking of many present-day apparatus by deposition of coke in reaction chambers and cracking tubes brings the process rapidly to a stop.

Further experimental work has been done in the investigation of effects of temperature, pressure and time,[23] in specially constructed apparatus, wherein extreme refinement of temperature and pressure control is possible and in which the effects are visible. Pressures up to 1500 lb. at varying temperatures can be used intermittently or continuously.

B. T. Brooks and H. D. Parker[24] have studied the volatile yellow colouring matter in cracked spirit and point out its similarity to the conjugated diolefins, in its readiness to polymerise in the presence of sodium or hot fuller's earth, and the reaction to sulphuric acid. Heat alone is sufficient to cause polymerisation at a temperature of 315° to 360° C.

Pure paraffin wax and medicinal paraffin, carefully purified over sodium, on being pyrolysed under regulated conditions, both yield the yellow coloured spirit which indicates that the formation of colouring matter cannot be due to the presence of oxygen or sulphur. The particular material has not yet been isolated.

H. Gault[25] has begun a study of thermal decomposition of hydrocarbons, paying special attention to the exact physical conditions involved in the reactions.

G. Egloff and J. C. Morrell[26] give interesting figures in connection with the production and composition of gases produced by cracking. These gases are of importance in the fueling of the process, and considerable progress has been made in the production of alcohols from them. Further work in making other derivatives should be both interesting and profitable, and the cracking of heavy residues for the maximum production of gas should especially stimulate such work.

Vapour phase processes, however, have not come into favour again, and are not likely to do so in the near future, as the economy in working liquid or partially liquid phase processes outweighs

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[22] *Journ. Inst. Petr. Techn.* **10**, 43.
[23] Dunstan and Pitkethly, *Journ. Inst. Petr. Techn.* **10**, 752.
[24] *Ind. and Eng. Chem.* **16**, 587.
[25] Les Matieres Grasses 197.
[26] *Ind. and Eng. Chem.* **17**, 32.

any other consideration at the moment, but Carl J. von Bibra[27] considers the possibilities of low pressure cracking, and suggests a process on theoretical grounds. The apparatus, similar to a shale retort, consists of a vertical column of refractory material filled with balls of a similar substance. These balls, covered with a film of heavy oil or asphalt, pass downward through increasing temperature zones, and the hot gases and vapours travelling upwards distil off any light oil, then as the temperature increases cracking takes place and finally the balls are covered with coke only. At this point steam is injected into the column and water gas is formed. The balls finally pass into a combustion zone where air is admitted to burn any remaining carbon. Complete combustion is effected, and the clean balls are raised to a hopper full of oil, to be coated again and return to the top of the column. The process is continuous.

R. H. Brownlie[28] submits that there is no basic patent in so far as existing heat and pressure processes are concerned. There was only one basic patent, and that was granted long before there was any demand for spirit.

Further investigation on hydrogenation or cracking in the presence of hydrogen under pressure has been undertaken by Shatwell,[29] who describes researches carried on at the University of Birmingham and by H. I. Waterman and J. N. Perquin,[30] who bring forward a mass of new experimental work of the greatest value.

The International Bergin Co.[31] protect hydrogenation in the presence of sodium to avoid previous desulphurising of Panuco or other sulphurous oils.

Col. Sir F. Nathan[32]. History and manufacture of tetralin by hydrogenation of naphthalene. Comprehensive tests of mixtures with benzol and alcohol.

A very valuable report has just been issued from the Bureau of Mines on "The Production of Gasoline by Cracking in the United States," January—April, 1925, compiled by G. R. Hopkins, Petroleum Economist.

The production of cracked gasoline in the United States in January, February, March and April, 1925, was 213,470,826, 185,964,090, 218,874,093 and 214,958,756 gallons respectively, representing 26, 24, 25 *and* 25 *per cent. of the total gasoline production* for these months as reported by the Bureau of Mines. Of the remaining 75 per cent., approximately 7 *per cent. is attribut-*

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[27] *Ref. and Nat. Gas. Mfr.*
[28] *Chem. and Met. Eng.* 31, 20.
[29] *Journ. Inst. Petr. Techn.*, 1924, 9, 10, 47.
[30] B.P. 212,661.
[31] *Fuel* 3, 346.
[32] *Journ. Inst. Petr. Techn.* 11, 736.

ble to natural-gas gasoline run to stills or blended at refineries, and 68 *per cent. to straight-run gasoline*, including what is known in California as "engine distillate."

Although the total gasoline produced by cracking in the Texas Gulf Coast area is greater than for any of the other divisions of the country, the Indiana and Illinois division leads in percentage, its cracked gasoline comprising approximately 40 per cent. of its total production.

Comparatively little cracking is being done in California. Only 2 per cent. of the total production of that State is attributable to cracking. If cracking was used to the same extent in California as in other sections of the country, the percentage for the United States would be approximately 30 per cent. instead of 25 per cent.

The Bureau of Mines' census of cracking plants shows that the operating capacity of the cracking plants in the United States is approximately 700,000 *barrels per day of charging stock*. Plants with a charging capacity of more than 100,000 barrels daily are now being built, and plants with a charging capacity of 25,000 barrels daily are now shut down. This represents potential equipment sufficient materially to increase the production of cracked gasoline. In addition to the raw material required for these plants, large quantities of gas oil and fuel oil now being burned under boilers are available if needed as a further source of charging stock for the production of gasoline.

In all there are 2527 cracking units operating in a daily production of 270,000 barrels for navy gasoline and a per cent. recovery of 33.

The Hydrogenation of Coal.

By H. G. Shatwell, B.Sc. (Vict.), M.Sc. (Tech.), A.I.C.

The liquefaction of coal, by hydrogenation, is now receiving considerable attention, and the results of some researches published during the past year have served to throw a certain amount of light on the mechanism of the chemical reactions involved.

It has been customary to regard the reduction of coal as being possible only under extremely high pressures, but Waterman and Kortlandt,[1] working at Delft University, Holland, have shown that such reactions are possible, even at a low initial pressure of 7 atm. Lematang brown coal from the Dutch East Indies

[1] *Rec. Trav. Chim., Pays-Bas*, 1924, **43**, 258.

was suspended in paraffin wax (previously found to be unaffected at the temperatures used), and heated in an autoclave at 423° C. with hydrogen and a mixture of carbon monoxide and steam respectively. The course of hydrogenation was indicated by temperature-pressure curves, and by the volumes and compositions of the gases used and recovered. Carbon monoxide and steam, because of the nascent hydrogen generated by their interaction ($CO+H_2O=CO_2+H_2$), appears to be a more efficient reducing agent than hydrogen itself. Thus, with the former, 100 grams of coal absorbed 7 litres, and with the latter 5 litres of hydrogen.

In a later investigation,[2] a semi-coke, prepared by the low temperature distillation of brown coal, was used. It was found that hydrogenation was brought about both with molecular and nascent hydrogen, hydrogen being taken up by the complex and oxygen removed as water and carbon dioxide.

No mention was made of the formation of liquid products. The authors concluded that semi-coke functions as a catalyst in the reaction $CO+H_2O=CO_2+H_2$, and suggested that in technical hydrogenations it would be preferable to distil the brown coal at a low temperature (500°—520° C.) and reduce the resulting semi-coke in a liquid disperse medium.

The liquefaction of some British coals has been studied by Graham and Shatwell,[3] and Shatwell and Bowen,[4] whilst a valuable paper on hydrogenation has been contributed by Fischer and Frey.[5] In the early experiments carried out in the University of Birmingham, attempts were made to hydrogenate clarain, the bright portion of a non-coking coal from South Staffordshire, without having recourse to the use of a liquid medium—*e.g.*, paraffin wax (Waterman) or a heavy mineral oil and the like (Bergius). Although treatment was carried out at over 400° C. for a period of 29 hours, only a trace of liquid was formed: thus, in all subsequent experiments, the powdered coal was mixed in the autoclave with phenol, and the latter subsequently removed from the products by means of caustic soda. Fischer and Frey, however, in their experiments at the Coal Research Institute, Mulheim, Ruhr, dispensed altogether with a liquid medium, used pebbles to stir up the coal during rotation of the autoclave, and employed pressures of hydrogen which can be considered as permissible only where a special bombproof shelter is available. The early failures at Birmingham, therefore, may have been due to the use of insufficiently high pressures or, what is more probable,

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[2] *Rec. Trav. Chim., Pays-Bas*, 1924, **43**, 691.
[3] *Fuel*, 1925, 25–30, 75–80, 127–130.
[4] *Ibid.*, 1925, 252–255.
[5] *Brennstoff-Chem.*, 1925, **6**, 69–79.

the employment of temperatures and concentrations of hydrogen which were too low for the object in view.

For purposes of comparison, the results of hydrogenating some non-coking and coking coals respectively are given in Tables I. and II. :—

TABLE I.

Non-Coking Coals.

Expts. at	Birmingham.		Mulheim, Ruhr.			
Source of coal.	South Staffs.		Shipley, England.		Schacht Lipine.	
	Clarain.	Durain.				
Treatments (a) ..	4	4	1	1	1	1
React. temp. °C.	410–437°	404–414°	450–470°	450–460°	410°–436	450–470°
„ time. hr.	13	16	2	3·5	2·75	4·75
Initial press. atm.	23–30	23–24	94·2	95·2	94·2	95·1
Max. „ „	143	120	255	270	262	287
Absorption of H_2 %	3·60 (b)	3·36 (b)	4·55	4·20	3·30	4·20
Oil yield .. %	37·7 (c)	37·5 (c)	—	63·2	—	19·9
Residue .. %	21·8	37·7	71·6 (d)	10·2	79·9 (d)	47·3
Gas and loss %	34·5	17·5	17·9	18·6	10·4	18·8

TABLE II.

Coking Coals.

Expts. at	Birmingham.		Mulheim, Ruhr.		
Source of coal	Graigola Seam, S. Wales.	Arley Seam, Lancs.	Lohberg Ruhr.	Lohberg, Ruhr.	Osterfield, Ruhr.
Treatments (a)	3	4	1	2	1
React. temp. .. °C.	406–430°	410–430°	460–488°	400–427°	490°–494
„ time	9hr.	12hr.	2hr. 50m.	2hr. 50m.	2hr.
Initial press. .. atm.	30–37	28–34	77	73·5–76·5	72
Max. „ .. „	137	127	223	232	201
Absorption of H_2 %	1·96 (b)	2·31 (b)	6·2	7·0	5·5
Oil yield .. .. %	26·1 (c_1)	61·4 (c)	28·5	36·8	15·5
Residue .. .. %	26·5	16·4	48·0	43·0	59·2
Gas and loss .. %	14·3	16·0	20·2	18·5	23·2

(a) Shows number of charges of hydrogen admitted during an experiment.
(b) Ash-free dry basis.
(c) Oil soluble in chloroform : C_1 soluble in ether, ash-free dry basis.
(d) Viscous or solid pitch.

Only the German experiments which gave the best yields of oil are included in the above tables, and a strict comparison of the results with those obtained at Birmingham University is not possible owing to the difference in technique adopted. Thus in the latter-mentioned work, the oil yield was taken as that portion of the product which was soluble in chloroform, based on the original ashless dry coal, whereas in the former the product was sometimes extracted with ether, and in other cases distilled

in a retort to 460° C. With regard to the use of a solvent, it has been found by Graham and Shatwell that chloroform is a better solvent than ether for the hydrogenated products.

A perusal of the above tables shows that the English and German experiments gave not radically dissimilar results. The pressures and temperatures employed by Fischer and Frey were considerably higher (with one exception) than those adopted at Birmingham, but the reaction times were longer in the latter case.

The following deductions may be made :—

(*a*) At lower temperatures, a longer period of time is required.

(*b*) The time factor is of great importance (see Lohberg and Shipley).

(*c*) At high temperatures, gas formation is materially increased (see Lohberg and Schact Lipine experiments).

(*d*) With Arley and Shipley coals, almost complete conversion to oil and gas has been effected.

As a result of their first experiments, Fischer and Frey concluded that coking coals, because of their tendency to agglomerate into lumps during treatment, are less readily liquefied than non-coking coals, which give a friable powder under the conditions of the experiment, and for this reason their later experiments were carried out with brown-coal and brown-coal semi-coke. The Birmingham research with the strongly-caking Arley coal, however, which gave a similar result to that obtained with Shipley coal, demonstrates that the tendency to coke can be inhibited by the use of a liquid disperse medium. In this connection, it is recalled that Bergius mixes a previously hydrogenated coal-oil with the coal to be liquefied, and though he states that such a procedure is necessitated from a technical standpoint, other considerations, such as that mentioned above, may come into operation.

Another point of importance is that relating to the hydrogenation of Graigola coal, which possesses a carbon content of 91·54 per cent. Thus the contention of Bergius, that only those coals which contain less than 85 per cent. of carbon (ash-free dry basis) are amenable to ready liquefaction, requires revision.

It is, in fact, somewhat premature to generalise as to which coals can, or can not, be liquefied under the conditions of the Bergius process, and much work requires to be carried out on the effects of time, temperature, pressure and hydrogen concentration before a theory can safely be enunciated.

Fischer and Frey finally investigated the hydrogenation of brown-coal (Union briquette), and of semi-coke obtained by distilling the brown-coal at 460° C. Some of their results are shown in Table III. :—

TABLE III.

Brown Coal and Semi-Coke. By Fischer and Frey.

Expt.	..	Low-temp. distillation.	23	25	26	27
Material used	..	brown-coal	brown-coal	semi-coke	semi-coke	semi-coke
Treatments ..	..	—	1	1	5 (*a*)	6 (*a*)
React. temp...	°C.	460°	455–465°	410–464°	415–454°	385–468°.
„ time ..	..	—	4hr. 15m.	5hr.	9hr. 30m.	14hr. 30m.
Initial press. ..	atm.	—	93·6	119·6	70·4–95·3	58–108
Max. „ ..	„	—	288	270	180–245	193–260
Absorption of H_2	%	—	4·5	6·3	11·4	10·6
Oil yield ..	%	7·7	21·5 (*b*)	29·6 (*b*)	35·7	45·2
Residue ..	%	59·3	23·7	46·0	38·3	6·1
Gas and loss ..	%	16·8	37·0	19·2	26·0	30·1
Alkali, soluble—						
% in distillate	..	50·8	27·8	—	—	—
% on orig. coal	..	3·9	6·0	—	—	—

(*a*) Residual gases liberated, oil distilled off to 300° C. from autoclave and fresh charges of hydrogen admitted the number of times shown.
(*b*) Distillate to 460° C.

The above figures indicate quite clearly that semi-coke is more readily liquefied than the brown-coal itself; that long-continued treatment (14·5 hours) is necessary to bring about complete conversion into liquid and gas (Expt. 27), and that the gas production is extremely high. The authors adduce that the physical nature of the raw material—*i.e.*, friability and surface area—is an important factor to be considered, and show that the oils, both from brown-coal and semi-coke, contain large proportions (up to 20 per cent.) of phenols. The experiments also support the contention of Waterman and Kortlandt that, industrially, brown-coal should first be distilled and the semi-coke then submitted to hydrogenation.

The researches briefly reviewed above indicate that a variety of coals, from brown-coal to steam-coals of high carbon content, can be liquefied by the Bergius Process. By suitable technique, either coking or non-coking coals can be used as the raw material. The factor which induces ease, or otherwise, of reduction is not known, whilst information as to the nature of the liquid products is almost completely lacking.

From the industrial point of view, the results, at first sight, are not encouraging. The question of optimum temperature appears to be of primary importance and may vary for each particular type of coal. Above a certain limiting temperature, a state of equilibrium will be attained in a short time but with the production of a maximum quantity of gas: below this limit, the reaction will proceed slowly with a maximum oil yield. The determination of the optimum temperature condition will, therefore, be a matter for experiment.

The time factor is also a matter of considerable importance, since Fischer and Frey found that Shipley coal required 3·5 hours' treatment at 450-460° C. for complete conversion, whilst under the conditions used at Birmingham, hydrogenation for about six hours was found to be necessary. Such long periods of treatment would make commercial exploitation of the process impracticable. It must be remembered, however, that in laboratory experiments where small bombs are used, the hydrogen atmosphere becomes rapidly exhausted, the reaction slows down and eventually stops. On the other hand, in a large-scale plant similar to that used by Bergius, hydrogen is constantly pumped round the circuit, the gaseous and light liquid products being withdrawn from the sphere of action and the coal kept continually in contact with hydrogen under constant pressure. Consequently, in a continuous process, there is little doubt that the time of reaction can be reduced to a limit which will render commercial operation feasible.

Finally, whilst the question of pressure may have, within limits, a certain influence on the rate of hydrogenation, it is probable that hydrogen concentration may be of greater importance. The extremely high temperatures and pressures used by Fischer and Frey bring into prominence the dangers inherent in these experiments, and if rapid circulation of hydrogen could be effected, it is probable that the same results would have accrued at substantially lower pressures and in a shorter period of time.

'Berginisation' of Emma-coal.[1]

By H. I. Waterman, Ph.D. and J. N. J. Perquin (of the Technical University of Delft, Holland).

The coal used for these experiments came from the Dutch Government colliery "Emma": Moisture, 1·55 per cent.; Ash, 8·7 per cent.; Volatile substance (calc. on dry coal): American method: 25 per cent. nitrogen (Kjeldahl), 1·7 per cent.[2]; carbon, 79·5 per cent.; hydrogen, 4·8 per cent., exclusive the hydrogen of the moisture, sulphur (method of Eschka 1·0 per cent., and method of ter Meulen 1·1 per cent.). By the treatment at 430°—450° C. with hydrogen of high pressure (pressure at beginning of the heating 110 KG/cM²) we succeeded in transforming the Emma-coal into

[1] A kind of coal from the southern part of the Province Limburg (Holland).
[2] This was the highest of the found percentages: 1·58 and 1·68 per cent. respectively.

oil for a very high percentage. For these experiments the coal was used in the form of a finely divided powder, and they were carried out in a rotating autoclave with conical joint and a content of ±2 L, received by one of the authors as a gift from the Bergin factory at Mannheim.[3] Pressure was indicated by means of a pressure gauge attached to one arm of the autoclave. By means of a mirror the pressure could be read behind the wall during the experiment. The autoclave was heated with gas flames; the apparatus was in order for rapid qualitative work, but not quantitative purposes, as the manometer became warm during the experiment. Therefore we could not be quite sure that the pressures read were right. From the table it follows that, notwithstanding this difficulty, we worked in a quantitative manner as much as this was possible.

To prevent the sticking of the coal to the walls of the autoclave, always we worked in a liquid medium. Iron balls were added to promote mixing. Meta-cresol was used as liquid medium, because cresols can be considered as a naturally ingredient of the low-temperature tar.[4]

Previously we did not succeed in transforming the Emma-coal (apart from the ash-content) quantitatively into a transparent oil free from "carbon." Bergius himself in a lecture speaks of a transformation of 85 per cent. obtained with a coal that contained 5 per cent. of ash.[5] In his important paper,[6] Bergius says that we must use by preference those kinds of coal that have a carbon-content (calculated on dry and ashfree substance) of less than 85 per cent. For the Emma-coal this percentage is $100 \div 89{\cdot}8 \,.\, 79{\cdot}5 = 88{\cdot}5$ per cent. Therefore our choice was unfavourable in this respect. Apparently the "Winterschlag" coal, with which the Belgian committee experimented, contained less than 85 per cent. From this coal they obtained a black, tarry liquid of high viscosity. This product was quite homogeneous and beyond mineral substance did not contain other particles of solid substance. The mineral substance was in a stable suspension ("sous forme de poudre impalpable"). They conclude that the coals of proper composition can be transformed wholly in a liquid fuel. They worked with powdered coal mixed with tar oil (2:1), while stones were added to promote mixing. The temperature to which it was heated was 434° C.; the hydrogen was introduced in

[3] We wish to express our thanks once more to Dr. F. Bergius for his kindness.

[4] Franz Fischer, *Umwandlung der Kohle in Ole*, Berlin, 1924, p. 39.

[5] *Z. angew. Chem.*, 1921, **34**, 219.

[6] *Loc. cit.* p. 346. Compare, too, F. Ranwez, P. Erculisse, P. Bruylants, M. Nothomb, "Le procédé Bergius, Ses applications en Belgique." Notice "Technique d'une commission constituée à l'initiative de F. Radelet." Compare, too, *Chaleur et Ind.*, 1923, **4**, 939.

the cold autoclave to an initial pressure of 100 atmospheres. 4 per cents. of weight of hydrogen were consumed. In a recent paper of Bergius,[7] too, a consumption of about 4 per cent. of hydrogen is mentioned and the coal (splint-coal from Upper Silesia with 28 per cent. volatile substance, 6 per cent. ash, 4 per cent. moisture) produced: 55 per cent. of oil, of which 22 per cent. neutral motor fuel boiling below 230° and 17 per cent. of higher boiling Diesel-oils, which contained about 5 per cent. phenols (chiefly not-gumming cresols), 16 per cent. of pitch, 15 per cent. of a gas that chiefly contained methane, 10 per cent. of water, 6 per cent. of ash, 15 per cent. of less changed coal-substance and 0·5 per cent. of ammonia. In opposition to the experiments mentioned in the report of the Belgian chemists the transformation of coal is not complete. In our berginisation experiments, indeed, we obtained a black, tarry liquid of high viscosity. But we observed that in the long run some carbon (with ash content) was deposited. Therefore it is very difficult to judge upon the yield of oil. Only when we have to do with absolute transparent oils, without coarse or more finely divided or even colloidal carbon, we can determine the accurate yield of oil. In the other cases we don't get a clear insight, especially in connection with the property of "carbon," to remain sometimes obstinately in colloidal solution.[8] Another difficulty is caused by the liquid medium. As mentioned, we used meta-cresol, which contained 0·5 per cent. of water, the spec. gr. (15°) was 1,035, the boiling point 196°-202°. In a blank experiment (No. 117*a* and *b*) 150 grams of meta-cresol were heated at 450° C. during about 6½ hours (in total) under high hydrogen pressure. The initial pressure was 110 KG/sq. cM. After the first heating, during 210 minutes, and after complete cooling, more hydrogen was added till the total-pressure again was 110 KG/sq. cM., there-after heating for the second time during 3 hours at 450° C. Not less than rather more than 24 gr. of cresol were not recovered and apparently had been transformed into gasoline and kerosene (6·7+1·5 gr.) on the one side and gaseous methane-hydrocarbons (6·1 L.) on the other hand. The average number of carbonisation in the gaseous hydrocarbons was 2·36. Besides, 7·8 gr. of residue had been formed, and at the same time a certain quantity of water: 4·3—0·75 (moisture of cresol)−2·1 (from the oxygen of the used hydrogen)=1·45 gr. The 24 gr. of cresol consumed during the decomposition: 124·0−98·8=25·2 L. of hydrogen. 4 gr. of water should be formed when the oxygen of the decomposed cresol had been expelled completely in the form of water. This is not the case, and therefore about two-thirds of this

[7] *Z. angew. Chem.*, 1924, **37**, 400.

[8] F.i. in asphalt. Compare F. J. Nellensteyn, *J. Inst. Petr. Techn.*, 1924, **10**, 311; H. I. Waterman and F. J. Nellensteyn, *ibid.*, 1925, **11**, 81.

No.	Quantity, gr.		Readings during the experiment.						Ingoing hydrogen in gr.	Obtained products in percentages of weight of the used raw materials (coal + cresol + added gas).			Sp. gr. at bij ± 15°.[3]	
	Emma coal.	Meta cresol.	Time to reach reaction temp. (min.).	Time at reaction temp. (min.).	Initial pressure (kg. per sq. cm.).	Maximum pressure (kg. per sq. cm.).[1]	Pressure cold (kg. per sq. cm.).	Temperature during reaction (° C.).		Oil.[2]	Gas.	Loss.		Gasoline –200.
93	200	400	30	90	110	310	97	450°	13·0	93·9	6·1		1·057	28·3
95	250	248	27	90	110	325	65	450°	15·5	81·0	7·2	11·8	1·043	27·6
94*a*	257	257	41	150	110	310	80	400°	15·0					
b			23	150	110	310	100	395°	15·3					
c			38	155	110	325	82	440°	15·6				1·096	15·9
98	250	250	30	150	110	355		400°[5] (395–415°)	—	66·0	28·6	5·4	1·032	2·02
101*a*	250	250	35	240	110	315	61	430°[6]	15·0					
b			25	180	105	325	78	430°	6·0					
c			30	180	110	340	90	430°	4·4	80·7	8·6	10·7	1·027	50·2
105*a*	250	250	30	240	110	315	52	450°[6]	14·9					
b			30	180	110	355	70	450°	7·9					
c			35	180	110	370	82	450°	5·4	77·6	13·3	9·1	0·988	67·6
112*a*	—	150	39	210	110	236	93	450°	10·1					
112*b*	—	—	32	180	110	243	100		0·9	89·5	10·5	0·0	1·029	6·7

[1] The readings of the pressure gauge probably are too high be
[2], [3] With suspended coal.
[4] The ingoing hydrogen contained oxygen; the O_2 content v
[5] The temperature could not be kept constant in this experim
[6] During the first hour ± 400° C.
[7] The mentioned numbers are relative to the oil poured off fro
During this operation each time explosions took place char
[8] Calculated on 189 gr. of coal because at experiment *a* and *b* v

Analysis of the oil.						Yield of gasoline calc. on the coal.	Added gases in L.			Gas obtained.								Added quantity (gr.) agst. gr. of iron balls.
Engler distillation in gr.										Total number of litres.	Sp. gr. compared with air.	Total weight in gr.	Number of litres.							
Gasoline –200.	Kerosene 200–300.	Cresol.	Residue.	Water.	Loss.		O_2.[4]	H_2.	N_2.				CO_2.	Heavy hydrocarbons.	O_2.	CO.	H_2.	Methane hydrocarbons.	N_2 (rest).	
28·3	24·8	384·0	119·6	15·0	6·3	14·2	1·8	145·2	—	—	—	—	—	—	—	—	—	—	—	250·5
27·6	56·0	210·7	98·2	19·2	6·3	11·0	2·2	173·1	—	105·1	0·273	37·3	—	0·4	0·2	1·5	77·2	24·7 $n=1·28$	1·1	87·0
							2·1	168·2	—	131·3	0·137	23·4	—	0·2	0·8	0·5	119·8	7·1 $n=1·30$	2·9	250·5
							2·2	172·1	—	144·6	0·105	19·8	—	—	1·6	0·6	129·5	10·0 $n=1·39$	2·9	
15·9	18·2	145·5	118·8	17·2	3·4	8·4[3]	2·2	174·8	—	134·0	0·163	28·3	—	—	0·8	0·7	119·1	11·7 $n=2·0$	1·7	
2·02	3·29	83·51	8·49	6·1	— [7]			—	157·3	160·6	0·958	200·0	0·1	—	1·5	0·1	—	7·2	151·7	251·0
							2·3	168·7	—											
							1·3	67·1	—											
50·2	39·9	194·8	118·4	16·3	9·4	20·1	0·8	48·9	—	137·3	0·256	45·7	—	—	1·6	0·7	92·5	39·4	3·1	251 0
							3·1	167·0	—											
							1·4	88·4	—											
67·6	32·8	213·4	78·4	16·2	6·6	27·0	1·0	60·8	—	140·8	0·389	71·3	0·3	4·2	0·8	0·8	94·8	35·2	4·0	251·0
6·7	1·5	124·7	7·8	4·3	—		1·5	124·0	—	106·0	0·1235	17·0	—	—	—	0·2	98·8	6·1 $n=2·36$	0·9	140·0

e too high because the readings are made when the pressure gauge is warm.

O_2 content varied between 1·0 and 1·9 per cent.
this experiment.

coured off from the graphite-like product (about 103 gr.). This graphite-like product had to be scraped off from the wall of the autoclave.
ok place characterised by detonations.
ent *a* and *b* was taken as a sample of the substance from the autoclave; coal was therefore withdrawn from the autoclave.

oxygen, apart from the small quantity of CO, must still be present in the oil fractions (f.i. in the residue). The cresols belonging to the constituents of the low-temperature tar, this decomposition process as such is of importance for the Berginisation of coal. The use of cresol as a liquid medium gives complications, and therefore we must correct the obtained results. The Belgian committee did not take into account this cause of error. For the present we will not make exact calculations from our observations at the coal experiments, there being more experimental work still necessary. Still we have proved :—

1. Berginisation of Dutch "Emma-coal" gives almost completely an oily substance still containing some suspended carbon.[9] This carbon in the long run deposes.

2. Very large quantities of hydrogen are consumed at the berginisation of this coal :—

	L. hydrogen,	Gr.	Duration, hours.	Temp.	Gr. of coal.
No. 95	96	8·6	1¼	450°	250
„ 96 *a*, *b*, *c* ..	147	13·1	27½	400–395–440°	257
„ 101 *a*, *b*, *c* ..	192	17·1	10	430–430–430°	250
„ 105 *a*, *b*, *c* ..	221	19·7	10	450–450–450°	250

The cresol, too, will consume hydrogen at berginisation, still the greater share will be used in the berginisation of the coal.

3. Large percentic quantities of gasoline and kerosene have been formed, namely, 90—100 gr. or about 40 per cent. of weight of the coal introduced into the autoclave (numbers 101 and 105). Without doubt a small percentage herefrom is formed by the decomposition of the used cresol, but certainly this is less than 10—15 per cent. of weight of the coal. Analogous coals in the coke factory, calculated on dry coal, give 3 per cent. of tar and < 1 per cent. of purified benzene-hydrocarbons[10], while at the low temperature carbonisation this coal in laboratory experiments on semi-commercial scale gave 5·6 per cent. (calc. on humid ash containing coal) of tar. From this the enormous technical advantage of the berginisation of this coal is clear. The competitive experiment with nitrogen was made at a temperature of 400° C., which was lower indeed, but still it is remarkable that the yield of gasoline and kerosene remains extraordinarily small. In connection with the observed explosion phenomenons of the products

[9] From this it follows that notwithstanding the unfavourable composition (carbon content, calc. on dry and ashfree product, > 85 per cent.) still berginisation occurs. This result is in accordance with the researches of Shatwell and Graham (H. G. Shatwell and J. Ivon Graham, "The Hydrogenation of Coal—I." ; *Fuel*, 1925, **4**, 25. Compare, too, A. W. Nash and H. G. Shatwell, *J. Inst. Petr. Techn.*, 1924, **10**, 865.

[10] D. P. Ross van Lennep, *De Ingenieur*, 1920, **35**, 127.

of reaction at the nitrogen experiment, this experiment was not repeated at high temperature.

4. From the quantity of methane-hydrocarbons formed we can expect that the hydrogen used in berginisation is certainly not completely, and probably only for a relatively small percentage, again discharged as gaseous methane-hydrocarbons. At experiment 95 only 24·7 L. of methane-hydrocarbons are found ($n=1·28$), therefore at the best 60 L. of hydrogen can be fixed, while 96 L. of hydrogen were used, and the coal as such give already at the heating methane-hydrocarbons (compare f.i. experiment 98, where heated with nitrogen).

The important quantities of formed water in the berginisation-experiments prove that in spite of the moisture in the coal and the formation of water from a part of the cresol and from a part of the oxygen of the hydrogen, a very great percentage of the oxygen content of coal is discharged as H_2O.

Refining.

By Professor A. W. Nash, M.Sc., F.C.S., M.I.Mech.E.

No changes of fundamental importance in refining have taken place during the last year, and improved refining methods generally appear to have received but little attention by practical refiners, more attention now being given to cracking.

Distillation.

Freeland (U.S.P. 1,516,285) has invented a new type of distilling apparatus, similar in design to a double pipe heat exchanger. The oil is sprayed into the inner tube at an angle with the object of imparting a whirling action in order to influence separation of the heavier vapours, presumably by centrifugal force, whereby these vapours are drawn from the circumference of the tube whilst the light vapours are taken off from the centre.

Heat is conveyed to the oil by means of steam circulating in the annular space between the pipes, and the inventor claims for his process simplicity, ease of control and economy in distillation.

Some interesting experiments have been carried out in the use of inert gases, in place of open steam, in the distillation of lubricating oil fractions by Gurwitch and Kaminer.[1] These investigators found that oil gas, used cold, gave distillation products of higher specific weight, flash point and viscosity, and their conclusions are that less

[1] *Brennstoff-Chem.*, 1925, **5**, 322.

decomposition takes place. Flue gases were found to have no protecting influence when used in this way, but the percentage of acid, calculated as sulphur trioxide, formed in the distillate, is considerably lower when oil gas or flue gases are used, than with steam.

A method of distilling topped crude oil, *i.e.*, without the gasoline and kerosene fractions, by means of superheated petrol vapours has been described by Wandyez, Sukuarowski and Chumura[2], as distillation of petroleum oil in apparatus with a relatively large heating surface. This apparatus comprised a boiler and superheater for the petrol, a distillation column, a condensing column, preheater for the oil, and a water-cooled condenser for the petrol vapour.

The capacity of the apparatus in which the experiments were tried was 2·5 kg. per hour. The petrol vapours were brought to the required temperature by means of the superheater and continually passed through the system until both the distillation and condensing columns had attained the correct temperature. The oil to be fractionated was then led into the top of the distillation column, in a similar manner to casing-head gas absorption plant practice, the distillation vapours, together with the heating vapours, passing into the condensing column, whereas the residues flowed to the bottom of the distillation column, whence they were led away for further treatment at a higher temperature. The more volatile constituents of the oil under treatment, which had passed through the condensing column, were condensed, with the petrol vapours, in the water-cooled condenser, separation at the end of the process being effected by distillation.

The residues from each operation were passed repeatedly through the apparatus, the whole of the oil under treatment being fractionated to asphalt by means of the petrol vapours, heated to successively higher temperatures. It is claimed that the products were brighter in colour than those obtained by the usual method of distillation, showed violet to green fluorescence, were transparent in thin layers, quite odourless, had viscosity at 100° (Engler) up to 8·7, and were easily refined. They compared favourably with those obtained from the same oils by distillation under high vacuum and by distillation with superheated steam.

For successful working the vapour pressure of the heating medium should lie as near as possible to that of the most volatile constituents of the original oil, and high-boiling fractions were not used.

In the distillation of oils containing sulphur, Sissingh[3] shows, contrary to the general belief that the sulphur content of distillation

[2] { *Przem. Chem.*, 1924, **8**, 201.
{ *Chem. Zentr.*, 1925, **96**, (I.), 595.
[3] *Brennstoff-Chem.*, 1925, **6**, 22.

fractions does not necessarily increase with increase in specific gravity of the fractions, and where decomposition, during distillation, takes place the middle fractions may be richer in sulphur than the higher fractions.

In this connection the nature of the crude oil plays an important part, and petroleums from different sources yield different proportions of sulphur in the various fractions. As an example of this a Mexican Panuco crude containing 5 per cent. of sulphur was distilled with superheated steam, and 13·09 per cent. of the total sulphur was obtained in the distillate up to 345°. In a similar experiment with Persian petroleum containing 0·98 per cent. of sulphur, the distillate up to 242° was found to contain 64·27 per cent. of the total sulphur. The loss of sulphur as hydrogen sulphide was found to be relatively small in each case.

When the Mexican oil was cracked under a pressure of from 100 to 150 lb. per sq. in. by the Burton method, the distillate was found to contain 16·63 per cent. of the total sulphur, whereas the gas contained 17·50 per cent. and 65·09 per cent. remained behind in the residium.

Prichard and Henderson have invented a new tubular type of distilling apparatus (U.S.P. 1,520,771), comprising a central shaft having, at the top and bottom, vessels containing the oil to be distilled. These vessels connect with one another by means of a number of tubes which pass through the shaft.

Hot flue gases also pass through the shaft, thus heating the oil as it circulates through the tubes, distillation taking place from the upper vessel.

To overcome the disadvantages of distilling oil in bulk, resulting in prolonged heating and consequent coke deposition and the formation of colouring matter, is the object of the "Boormann"[4] system of distillation. The crude oil passes through a preheater, where any water it may contain, together with the gasoline, kerosene and part of the gas oil, is driven off, the residue then passing down a distillation column where it is continuously distilled by means of superheated steam similar to the practice carried out in the alcohol industry. Presumably the same care would need to be taken to insure that a steady flow of steam at the constant pressure required was always available, otherwise there would appear to be a possibility of the oil remaining on the plates or even flowing down through the perforations and so spoiling the process. It is claimed that all the heavier fractions, down to asphalt, may be distilled in this manner, and also greater efficiency, cheapness and reduction of fire risks results.

An interesting contribution to the technique of high-vacuum

[4] *Petr. Times*, 1924, 12, 649.

distillation of an asphaltic base residue, from which the fractions up to kerosene had been removed by topping, is made by Allner[5], and the temperatures of the cuts given show the value of this method of distillation, although the vacuum maintained was not so high as the maximum vacuum obtainable in practice with the barometric condenser, when worked efficiently.

The plant consisted of a battery of six effective cells, each connected with a dephlegmator and tubular cooler, so that fractional condensation took place.

The temperature rose in each successive still of the series as well as the density, flash point and viscosity of the products: the content of hard asphalt increased abruptly in the product of the fifth still. The yield consisted of 8–10 per cent. of gas oil, 17 per cent. of "thinning oil" for addition to lubricating fractions, 40 per cent. of machine oil, 5 per cent. of cylinder oil, and alternatively 17 per cent. of pitch with 3 per cent. loss, or 8 per cent. of coke and 10 per cent. loss. The cuts for gas oil, spindle oil and machine oil were at 125°, 160°, and 225° respectively. A considerable amount of kerosene was obtained by sending the vapours, after passing the tubular condenser, through a water condenser, the permanent gases being removed by a pump. A vacuum of about 450 mm. was maintained. The yield of lubricating oils was 55 to 60 per cent. of the raw material.

Refining.

More attention seems now to be given to physical methods of refining than hitherto, and in this connexion an interesting and instructive paper has been published by Dunstan, Thole and Remfry[6] on the use of bauxite as a refining agent for petroleum distillates.

After stating that the most effective substance for removing odour, colour, and flavour from liquids are inorganic gels, formed by dehydration of a hydrogel such as silicic acid or aluminium or ferric hydroxides, the authors deal with bauxite and compare its decolorising and desulphurising properties with those of floridin, to the latter's advantage as a decoloriser but not as a desulphuriser. The best result obtained with bauxite was when the material was freshly ignited immediately before use and not allowed to absorb moisture from the air: filtration gave superior results to the agitation method and sieving to 30/60 mesh was found to be the best size for desulphurising, whereas for decolorising a finer mesh gave better results. In works practice 20/90 mesh is employed. The mechanism of the reaction is purely one of surface adsorption, and

[5] *Petroleum*, 1925, **21**, 5.
[6] *J. Soc. Chem. Ind.*, 1924, **43**, 180 T.

for this purpose bauxite is admirably suited, as it contains a large number of ultra-microscopic pores, thus giving an enormous surface area. The experimenters found that colour was eliminated preferentially, and that until about 85 per cent. of the total colour had been removed, practically no adsorption of sulphur compounds took place.

Bauxite also possesses the property of inducing both decomposition and polymerisation of unsaturated hydrocarbons. Two methods of refining cracked spirit by bauxite are mentioned: (*a*) by filtering at 100° C. whereby the unsaturateds are polymerised to gums and washed out by the oncoming liquid; these are eliminated by redistillation, the relatively non-volatile gums being left behind in the still; and (*b*) by passing the spirit in the form of vapour through bauxite at 200/220° C. The condensate is colourless and free from the usual bad odour of cracked spirit, as the gums are left behind in the filtering agent.

For ordinary refining, filtration through floridin, followed by filtration through bauxite, would appear to give the best results. The efficiency of raw bauxite is determined by its moisture content, which is a measure of its pore space, and by noting the quantity of heat evolved when bauxite is moistened with kerosene: chemical composition appears to have no connection whatever with adsorptive efficiency.

Smith and Ziser,[7] in their U.S.P. 1,507,692, describe a plant for the purification of light petroleum oils, which removes the gumming polymers formed in light oils by polymerisation as a result of exposing such oils to heat and light, and also the petroleum acids which are formed by this ageing process. The latter, after neutralization with caustic soda, together with the polymeric substances, can be removed by agitating the oil with a small quantity of acid clay.

The tendency of cracked gasolines to turn brown on keeping, producing a disagreeable odour and gummy deposit, is the subject of investigation by Liddell[8], who has found, by submitting the gasoline to the catalytic action of fuller's earth in a tower, whilst in a state of vapour, that better results were obtained than by washing the spirit with acid. The gasoline is refined with a loss of from $\frac{1}{2}$ to $\frac{3}{4}$ per cent., against 4 to 5 per cent. in acid refining, the diolefines condensing out as a yellow to orange red liquid, which is returned to the stills for the further recovery of gasoline. The less volatile fraction of the coloured liquid, when isolated, has drying properties. In practice it has been found that from 100 to 400 barrels of gasoline, according to the quality of the spirit, can be refined by one ton of fuller's earth, the latter turning black in the process, but is regenerated by heating.

[7] *Ind. Eng. Chem.*, 1924, **16**, 587.
[8] *Chem. Met. Eng.*, 1924, **31**, 975.

With the apparatus working in conjunction with pressure stills a saving in operating costs of 7 cents per barrel has been made, an increase of 8 per cent. in gasoline produced, and sulphur-containing kerosene refined by this method give good burning tests.

Truesdell[9] also deals with a similar process developed by Gray of treating pressure distillate, in the vapour phase, with fuller's earth. The original distillate, after redistillation, is passed, whilst still in the form of vapour, through a bubble tower into the Gray vapour treating tower, which is a cylinder, mounted on structural steel supports containing an inner tower, having a conical bottom fitted with a manhole for emptying purposes, which holds the clay ground to 60/90 mesh. The top of the fuller's earth container is open, and considerably lower than the roof of the outer one, and at the bottom are plates perforated with a number of small holes suitably screened: heavy lagging causes a high temperature to be maintained in the clay.

The vapours are led into the annular space, where any condensation is refluxed back to the still, forced up to the roof, and then downwards through the clay; the treated vapours flowing out at the bottom of the tank and the polymerised products are discharged through the perforations to the still. The clay is regenerated by roasting, and is used as many as four or five times.

Clemens (U.S.P. 1,523,053) has taken out a patent for a similar process, the apparatus in this case being merely a dome, carrying a bed of fuller's earth, attached to the still. A pan is suspended beneath the dome to catch any particles of earth which may fall through the perforated floor.

It is interesting to note that Remfry E.P. 212,500, advocated the use of activated charcoal on the same principle some considerable time ago; and Dunstan, Thole, and Remfry have also given this method of refining, using bauxite.

A method of separating saturated and unsaturated hydrocarbons is given by Johansen, U.S.P. 1,520,953. The oil is shaken with dilute soap solution when the unsaturated liquid hydrocarbons are found to emulsify more readily than the saturateds, and can be removed, almost completely by suitably adjusting the concentration of the soap solution. The process is said to be particularly useful for separating hydrocarbons of similar boiling point.

Clarke (U.S.P. 1,521,278) has found that by treating petroleum distillates, having a high sulphur content, with sulphuric acid 1·84, and then, after separation of the sludge, by redistillation, a residue of high sulphur content is obtained which is again treated with acid. A distillate of low sulphur content is said to be obtained with minimum refining loss.

The action of sodium plumbite on "sour" oils is discussed by

[9] *Nat. Petr. News*, Feb., 1925.

Wendt[10] in an article which appears to be based on the findings of Wendt and Wiggs.[11] Some oils are stated to owe their property of reactivity with sodium plumbite to the presence of hydrogen sulphide or mercaptans; the former, being a gas, tends to accumulate in the light fractions, and being completely removed by caustic soda, its elimination presents no difficulty, and the addition of litharge is unnecessary. By allowing heavier oils to stand for a few days, or by blowing or boiling, sulphuretted hydrogen is easily eliminated. Mercaptans present certain difficulties, however, in their removal, as being oils and not gases, they cannot be removed by boiling or blowing. If treated with caustic soda they are changed to sodium mercaptides, and these being partly soluble in the oil, refining is incomplete. When lead is present, however, insoluble lead mercaptides are thrown down completely, and the addition of sulphur is only necessary with heavier oils, the action being to oxidise the lead mercaptides to the corresponding disulphides and lead sulphide, the formation of the latter causing the darkening in colour, as a result of the addition of sulphur. Free sulphur, when present in an oil, acts in the same way. The disulphides, being comparatively sweet and not reacting with plumbite, are considered sweet; but it is pointed out that the actual sulphur content is not reduced unless free sulphur is present, when it is removed as lead sulphide.

Sissingh[12] states that the "Doctor Treatment," as applied in practice, is, in its present form, not applicable to crude Mexican distillates. In these the sulphur can go into solution, and a beautiful sulphur crystal was observed some months after in a distillate which before (after the "Doctor" treatment) had been treated with sulphur. Borneo distillates can also dissolve sulphur, thus leading to a considerable increase in the sulphur content, and as it would be dangerous to treat oils with sodium plumbite solution without sulphur, because of the formation of lead containing deposits, this method of refining is not advised for the oils in question.

The results of some interesting experiments have been made public by Wood, Lowry and Faragher[13] on the action of petroleum refining agents on pure organic sulphur compounds dissolved in naphtha. This investigation represents a quantitative study of the effect of sulphuric acid, sodium plumbite, copper oxide, sodium hypochlorite and aluminium chloride in naphtha solutions of mercaptans, alkyl sulphides and thiophene and some qualitative observations on naphtha solutions of hydrogen sulphide, free sulphur,

[10] *Petr. Age*, 1925, **15**, 17.
[11] *Ind. Eng. Chem.*, 1924, **16**, 1113.
[12] *Brennstoff-Chem.*, 1924, **5**, 234.
[13] *Ind. Eng. Chem.*, 1924, **16**, 1116–1120.

carbon disulphide, sulphoxides and sulphones. The results are too bulky to set down in a resumé, but are worthy of study by those interested.

Petroleum Geology.

By J. E. Marshall Hall, A.R.S.M.

With a growing demand for Petroleum the supply of geologists who specially apply themselves to the problems of finding it is ever on the increase. The work of summarising the actual exploitation and development of known petroliferous fields, and the exploration of others hitherto untapped, is a difficult one; it is proposed here merely to glance at some of the papers read during the past twelve months, which will serve to indicate the widespread nature of the researches, and then to consider such advances as are concerned more particularly with the geologist's knowledge of petroleum *per se*.

1.—Field Work and Exploration.

Canada.—Mr. G. S. Hume, in a paper on "The Oil Situation and Prospects in Canada," directs attention to Ontario and Alberta, with the likelihood of oil-fields in the Fort Norman Area. New Brunswick is also producing oil in the Stony Creek field, Albert County.

Australia.—Although no oil has yet rewarded the persistent efforts of prospectors, much work has been done. Dr. Wade considers that the marginal portions of the Fitzroy area of Western Australia is the most favourable. Another authority, Captain E. de Hautpick, after a detailed survey of large areas, recommends the Tertiary marine sedimentary basins of the ancient Murray estuary, South Australia, and possibly Gippsland, Victoria. He also thinks well of the coastal Tertiary margins of North Tasmania, and the Tertiary marine sediments of New Guinea, and is also a believer in New Zealand as a probable oil-country in the near future.

Sarawak.—In the April number of 1924 of our Journal is an abstract of the Hon. T. G. Cochrane's paper upon "Empire Oil: the Progress of Sarawak." The production is stated to be second only to that of Burma, the largest producer in the British Empire, and is on the increase.

Persia.—A very interesting paper upon "The Geology and Oil Measures of South-West Persia," by Mr. R. K. Richardson, gives us some of the latest work upon the main centre of activity under the Anglo-Persian Oil Company's auspices. It demonstrates the

stratigraphical and palæontological work being carried on by the staff. This, combined with a careful study of the tectonics, leads him to consider the "Asmari Limestone" as the original source of the oil. This view was supported in the discussion by Mr. E. H. Cunningham-Craig, and by Mr. S. Lister-James, the Company's chief geologist. The latter stated that this fact would form the basis of their further search for oil-fields in the country.

Argentine Oil-fields.—Mr. Campbell M. Hunter read a paper in November upon this subject, in which he gave a geological survey of structure, followed by details of the oil-producing centres. He considers the prospects of developing an important oil-industry in this country as "more than promising."

Mexico.—In a paper on "The History and Geology of the Oilfields of Mexico," Mr. C. A. Sansom, after alluding to the restriction in operations due to revolutionary troubles, says that real success has been met with in the Cacalilao district, where 100 millions of barrels have been produced yearly. Drilling is being continued in the Isthmus, which, with the States of Tabasco, Yucatan, and Quintana Roo, are considered as the most promising areas at the present time.

The abstract of a paper by Mr. Wm. F. Jones (February 19th, 1925), upon "Tabasco Geology in Relation to Petroleum," also indicates the geological research that has been expended lately on this region.

Alaska.—Explorations took place in 1923 under Mr. A. H. Brooks (Chief Alaskan Geologist, U.S.A. Geol. Survey), and were not unfavourable to the existence here of a fresh oil-field.

Peru.—The London and Pacific Petroleum Co. (the pioneer company) produced 5 million barrels of the finest oil in 1923, and expected to produce 1,000,000 tons in 1924. Further exploration is commended in view of the widespread existence of oil.

Kamtschatka.—A large expedition is being organised, specially directed towards the search for naphtha. This results from the work done by M. Potervoy, during the early part of 1924.—("Oil-seeking in Kamtschatka," *J. Inst. Petr. Techn.*, X, 159A.)

Allusion may here be made to the State boring near Winterswijk in Holland, where researches are being carried out, also the work carried on by the Czecho-Slovakian Government in the south Moravian plain, and to M. Georges Rupalley's important account of his geological work in the new kingdom of Jugo-Slavia, whence results should shortly come to hand, as the country is evidently rich in oil. These last examples will serve to illustrate the fact that fresh fields are being eagerly sought for, and under very favourable auspices.

2.—Tectonics.

Northern Africa.—A paper by M. Joleand has appeared in the later numbers of the "Revue Pétrolifère," dealing with the Atlas System from a broad point of view, and giving an analysis of the history, palæography, and structures to be seen in Barbary—including under this name Algeria, Morocco and Tunis. Mr. Joleand having spent over twenty years in Northern Africa thus contributes much valuable information on a portion of this too little known area. He also sketches out the principal groupings that exhibit signs of bitumen, petroleum, and combustible gases. The whole subject is dealt with by the hand of a master, and, although complicated, is made both interesting and instructive to geologists.

Jugo-Slavia.—Referring to M. Georges Rupalley's paper, a comparison is drawn between the tectonics of this country and those of Rumania and Galicia, affording further data upon the interesting "problem" of the Carpathians.

Andes.—Mr. Hunter, in his account of the Argentine fields, also gives details of the work done in the Sub-Andean system by various geologists, and his paper deals with the different tectonic movements as affecting the Cerro Lotena-Plaza Huincul area formation.

Persia.—Mr. R. K. Richardson deals with the Zapos arc and its associated ranges in Persia as a Southern loop of the great Alpine Himalayan belt, and goes into considerable detail. A tabular representation is given showing the sequence of folding movements.

It may be taken for granted that tectonics are receiving a special amount of attention by oil geologists, which is not unnatural, so many fields occurring in disturbed regions.

3.—The Origin of Petroleum.

Enterprise has accomplished so many feats by means of temporary hypotheses and upon purely empirical data, that it is necessary perhaps to stress the importance of this matter to the geologist in regulating his work in the field. In his case this question of origin is of vital importance. A very thoughtful lecture upon this subject is that of Mr. Lancaster D. Burling (Mining & Geol. Inst. of India), which presents very fairly, in a quite unbiased manner, the present state of geological opinion. We hail with pleasure the manner in which he has brought forward this matter, and hope that it will result in further collaboration between geologists. We are agreed that the problem should rather be stated as "The modes of origin of Petroleums." To take a narrow and limited view of the matter is certainly to shut our eyes to many salient facts, and this wider outlook is likely to be more fruitful in

its practical results. A brief consideration of the author's mode of treating his subject will be of interest.

With the question, "What do we know?" he rehearses the observed occurrences of Petroleum, inorganic and organic. In connection with the former he mentions various meteorites, and also the presence of petroleum in quartz crystals. Next come various occurrences in connection with igneous rocks, suggesting that they may have been derived from country rock.

The instances cited as organic are naturally numerous in connection with fossil forms of fish, molluscs, foraminafera, algæ, lignites, drift matter of vegetable origin, diatoms, etc. He then gives several instances of petroleum now in process of being formed in bays of the Red Sea, in the coral reef muds, in the Gulf of Suez, in peat bogs and many others.

The differences in character are then mentioned, from field to field, from horizon to horizon, and he notes that the solid bitumens are sufficiently distinct for mineralogists to classify them under different names.

Next comes the association of petroleums with gas, salt water, gypsum, salt, sulphur and other substances.

From observed facts the author passes to experimental production, from inorganic materials and various carbides yielding acetylene and other hydrocarbons, from many lavas when heated, and then from numerous organic materials such as fish oils, wood, coal, diatomaceous ooze, etc. Numerous properties are then mentioned, such as the decrease in specific heat with increase in molecular weight, and the rapid falling off in latent heat under a like condition—that the co-efficient of expansion varies inversely with the density, the range in specific gravity, and the relation between this and the chemical composition of the hydrocarbons.

Passing to the composition, he notes that all hydrocarbons fall into a number of groups, saturated and stable (C_nH_{2n+2}), unsaturated and unstable (C_nH_{2n}) acetylenes, benzenes, all of which have been formed in petroleum. Eight of these groups are mentioned, and each represents a series of homologous, isomeric and polymeric bodies. The petroleums made up of these hydrocarbons, of which no two appear to be alike, all have the common designation of "petroleum."

Oxygen, helium and nitrogen are generally constituents of petroleum, the latter usually in the form of complete organic bases.

The organic origin may perhaps be inferred from the last-named element, though it is not in very large quantity. The older and deeper oils do not contain the most nitrogen, which it is suggested may be due to the breaking up, with age, of nitrogen compounds. There seems to be a chemical difference between the bitumens in primary and in secondary deposits (Stremmeuber).

The author then considers the various hypotheses as to the origin of the hydrocarbons:—

(*a*) Inorganic, such as Coste's volcanic origin, the cosmic origin, formed during the consolidation of the planet (Sokoloff) and several others.

(*b*) Organic. These are too numerous to be detailed here, and the controversies between animal and vegetable sources are alluded to. This part of the paper is of great interest.

Starting with the original differences in the hydrocarbons, the various hypotheses causing alterations in them is considered, and those dealing with the formation of the solid bitumens (asphalt, etc.).

Finally, the "conclusion" is arrived at—and here the author italicises the term "petroleums," instead of petroleum, and suggests that it is erroneous to seek for a simple explanation, disclaiming at the same time any originality in this conception. Indeed, the tenor of the paper is that we have a legacy left us by all the previous workers which must be utilised. The hope is expressed that the study of petroleums will be undertaken in the way that science has studied minerals. The papers of the future will then be on the origin of particular oils; those derived from diatomaceous shales, bituminous limestones, etc., on the oils associated with rocks having particular mineral assemblages, primary or secondary, and so forth. The paper maintains to the end the scientific and detached outlook which is its characteristic feature and its most valuable asset in the consideration of this complex question of origins.

In the above résumé it will be noted that the inorganic origin is practically shelved as of no practical importance. It will perhaps not be uninteresting to give some account here of the cosmical hypothesis. It has quite recently found a strong advocate in Prof. Ewald Pyhälä, of Helsingfors, who contributes a paper in the June number of *Petroleum Zeitschrift* (this is noted below). The following remarks are taken from Mr. H. W. Dixon, in the discussion following upon a paper by Mr. David White, on the "Genetic Problem Affecting the Search for New Oil Regions." The latter holds by the organic origin.

Mr. Dixon, in disagreeing fundamentally with the ordinary view that mountain ranges originated in the crumpling of the earth's crust owing to contraction, put forward the view that the gaseous hydrocarbons are in the interior of the earth for the same reasons as the other gases, because of the diffusion of gases in this planet, itself originally gaseous. He thinks they have remained there ever since consolidation of the crust occurred. The change from the gaseous to the solid condition is by loss of temperature: the solid part then becomes lighter, because the gaseous core must be denser

than the solids that lie upon it. The gases, by reduction of density, cause elevation, just as the surface of a loaf of bread is "raised."

According to the contraction on cooling theory, it has been calculated that the loss of heat in the earth's interior during the last 100 million years would give rise to a circumferential contraction of about seven miles; whereas if all the folding and faulting and overthrust of the various mountainous ranges were ironed out, they would indicate between 150 and 200 miles.

Mr. Dixon remarks that there is a decided difference here "that has to be accounted for."

We leave the matter here, merely adding that this inorganic exponent will probably fall as foul of the mathematicians as the upholders of the organic theories do with the chemists.

Mr. Pyhälä (already alluded to) approaches this matter from another point of view. The paper is somewhat voluminous, as Sheridan is credited with describing the Decline and Fall in his panegyric to Mr. Gibbon in the House of Commons (lowering his voice, however, at the commencement of the adjective !).

His conclusions may be briefly stated thus :—

In an earlier paper he states that he was able to verify an assured connection between the most recent zones of mountain foldings with the seismic and volcanic elements accompanying them and the most important petroleum production of the world : *e.g.*, the occurrences are so closely connected with each other that there seems to be a law which would support the volcanic origin of petroleum, such as Ion Humboldt some 120 years ago declared to be highly probable.

The argument is summarised as follows :—

1. There is a very high temperature in the interior of the earth, in consequence of which the internal core must be considered as amorphous and fluid. This contains compounds rich in energy—carbides and so forth—which by chemical transpositions develop heat, which tends to replace the heat lost by the earth.

2. By observations of Nature and by experimental work Emile Retoh was convinced that water reaches the interior, which by known chemical processes causes an increase in volume of the mother-rock masses taking place through the heat evolved during these reactions, and thus gives rise to the manifestations of Volcanism.

3. From the carbides petroleum is formed, as Ion Humboldt declared, as a Professor Mendeleeff has described.

4. Volcanic upheavals, and especially the laccolite formations which often occur, and by which domes are formed in the overlying rock beds, and the fact that fissures are originated, offer outlets for this fluid or gaseous petroliferous material, enabling them to reach the upper beds, which will quite simply explain the formation of the most important oil-fields.

5. It would be expected that in crater eruptions amongst other inflammable gases, and carbonic acid, steam, etc., petroleum vapours would be evolved, but these would be completely oxidised.

6. Petroleum may also be a by-product of the reactions that occur in the earth's interior. These processes, working periodically, are also doubtless active.

So much attention has of late been paid by authors to this question of the Origin of Petroleum, that it seemed advisable to quote some of the most recent at some length : the knowledge that many minds are at present occupied with these matters will perhaps lead others to think seriously on a matter so often shelved as of minor importance.

By the kindness of Mr. W. R. Macdonald, who has recently returned from field work in Persia, using the torsion balance, the following notes are appended :—

4.—GEO-PHYSICAL METHODS.

By Mr. W. R. Macdonald.

Gravitational measurements are at the present time receiving a considerable amount of attention by geologists to enable them to clear up some of the outlying areas where geological evidence is not available.

In general, where these conditions exist the regions are usually covered by an alluvium drift such as desert areas, etc. and which, being usually flat, enables the gravitational methods to be conducted under suitable conditions. The gravitational torsion balance is an instrument capable of being used to elucidate underground geological structures, as, owing to its extreme sensitivity, it enables variations in the force of gravity to be measured, and thus by calculation changes in underground conditions can be recorded in relation to their form and mass.

The instrument itself consists essentially of a light beam, suspended in space horizontally. One end of the beam is loaded with a known weight and the other end is balanced by a similar weight suspended vertically downwards by a thin wire attached to the end of the beam.

This balanced system carries at its centre a short, vertical rod, and to this is attached a fine suspension wire which enables the whole system to be suspended in space.

Wherever the force of gravity acts in any direction other than vertically the instrument is subject to a torque, from which, after turning the instrument in five positions of azimuth, four important values can be determined—viz., the magnitude and direction of

the greatest change in the variation of "g," and the direction and magnitude of the rate of change of curvature of the gravitational potential field, which varies according to the form and mass of the underground structure.

To expedite observations a double system of balance beams are used, being arranged at an angle of 180° in relation to their suspended lower weights. With this instrument only three positions of azimuth are required.

Automatic photographic registration and visual telescopic methods of observations are provided to observe the deflections of the beam due to gravitational forces.

Baron Von Eotvos was the original inventor—a well-known scientist. This whole subject had been worked out by him thirty years ago, so it is somewhat surprising that such an important application in assisting geologists should have remained so long in abeyance.

The whole subject can now be studied at length, and is past the experimental stage, as several oil companies have established departments for dealing with the torsion balance in particular, and geophysics in general.

For a practical account of the torsion balance survey undertaken by the Anglo-Persian Oil Company, the writer's paper, read before the Department of Scientific and Industrial Research, which is a Government Department, might be consulted, as it gives an account of first-hand experience.

With regard to the possibilities of the torsion balance and other geophysical methods, it is quite clear to the writer that one of the conditions of success for all operations depends largely on the accuracy with which all available geological evidence in the surrounding district has been noted and correlated. By this means the gravitational measurement can be at once illuminated to reflect valuable result, which by experience has now proved to be the case.

Drilling Methods and Tools.

By Ashley Carter, A.M.I.Mech.E.

The outstanding improvements in drilling methods and tools during 1924 have been in the direction of standardisation and manufacture, under which latter, seamless casing has received particular attention.

The American Petroleum Institute appointed various committees to deal with proposals for standardisation of drilling tools and joints, rigs, boilers, wire rope, belting, etc., and the results of their investi-

gations, in some cases not yet completed, were submitted at the Fifth Annual Meeting of the Institute, held at Fort Worth in December, 1924.

The committee charged specially to consider the question of steel and iron tubular material had not completed their investigations by the end of 1924, although it was hoped to do so early in 1925. The complete standardisation of the various sizes, weights, thicknesses and threading will be of great advantage to the oil industry in general. The committee is of opinion that a material which will meet the requirements of strengths of walls, and tensile strength of casing, with a two to one factor of safety, should be adopted. Provision is proposed to be made for identifying the different sizes and weights. They are further of opinion that a specification for a better grade of material from which the pipe is made, has become necessary. Another most important step is the recommendation for uniformity of pitch and diameter of thread and of taper of thread. The adoption of standards of size and manufacture will effect a great reduction in the number of sizes of pipe, resulting in a saving in cost, and in the difficulties and hazards of the user. Specifications now call for a greater average length of all grades of pipe, up to as much as 30 feet in length, as compared with the previous random lengths of 18 to 20 feet. This will facilitate handling in the field, and a proportionate reduction in joint difficulties.

The earlier method of manufacture of oil-well casing has been the welding process, the metal in this case being rolled into strips, which are subsequently curved into cylinders, and the edges welded together. Casing of this type, known as "welded casing," is necessarily made from metal which is readily weldable, the choice being restricted to wrought iron, or low carbon steel. Both of these metals being relatively soft and weak, welded casing is subject to a definite limitation in its ability to meet the requirements for tensile and collapsing strength. The seamless process of manufacture, which is being used, is intended to overcome this limitation. The process consists of rolling the metal into round bars, piercing an opening through the bars from end to end, and elongating the bars. By this means it is possible to produce casing from high carbon steel, or alloy steel of any desired degree of strength, provided that the metal is not too hard to permit the cutting of threads.

In order to obtain information on the tensile strength of screwed-up joints in casing of different grades of steel, numerous full-size specimens were tested to failure at the Carnegie Institute of Technology.

Tensile tests on strips cut from the specimens have given an average ultimate strength of 53,000 pounds per square inch for steel used for the welded type of casing, as compared with 88,000 lbs.

per sq. in. for that used in the seamless type. Tests on 6¼ in. and 6⅝ in. sizes of casing showed a gain in tensile strength (or pulling-out strength) in casing made from high carbon steel as compared with low carbon varying from 58 to 114 per cent., with an average of more than 75 per cent.

One important point has been carefully noted, namely, that of the question of whether the pulling-out strength is affected by the initial tightness of collars, and has been cleared up in the investigations. The tightness of the initial screwing-up of the collars was found to affect the pulling-out strength only as far as it affects the number of threads in contact. As the variation in this number would usually be small for any amount of screwing-up used in practice, it is considered that pulling-out strength is practically independent of the initial tightness of collars.

The committee appointed to investigate the question of cable-tool drilling joints have reported that they anticipate reducing the existing number of different gauges from 356 to 11. Provision is being made for the accurate maintenance of all gauges, thereby ensuring interchangeability.

Oilfield boilers are being investigated with a view to standardisation, and the suggestions put forward embody interchangeable fittings and standardised dimensions of the boiler structure.

Standardisation of rotary drilling equipment is being similarly considered, and several recommendations have already been made.

Careful supervision of the methods of heat treatment and bit dressing has been found to result in considerable saving of time hitherto lost in the changing of bits.

Fishtail bits are recommended in six specific sizes. Draw works were found to present some difficulty on account of the different drum designs, and that to attain interchangeability would necessitate other dimensions, especially on clutches and clutch sprockets. Line shafts have been recommended for standardisation in three sizes, and tolerances on the fits of shafts, sprockets, keys and key ways have been adopted.

As regards rotary tool-joints, field tests have been carried out, and definite recommendations will be made on completion.

Four different sizes of square type grief stems and three-fluted type are being recommended.

Wire drilling lines and manilla cordage have been considered, with a view to standardisation, in which connection diameter of sheaves have received special consideration. Rust-resisting wire rope has been satisfactorily manufactured, and has given good results in cases to which it has been particularly applicable.

Core bits have been markedly improved by the introduction of renewable knives, both for coring shoes and reaming knives.

The year 1924 has seen the development of an automatic electric drive for rotary outfits, whereby automatic feed of the drill-pipe and bit is assured. This is brought about through the use of a differential between two reduction gears and two motors, which automatically and instantaneously varies the pressure of the bit according to whether hard or soft formation is encountered. The control of the feed is thus mechanically performed and twist-offs of the drill-pipe, which are the most frequent sources of fishing operations in rotary drilling, are eliminated. It is possible to drill a well quicker, straighter and more economically, with less hazard and wear and tear on the drill-pipe and equipment. The results so far obtained have amply justified its introduction. The apparatus possesses the advantage of being applicable to any standard rotary outfit.

Oilfield Engineering.

By Professor A. W. NASH, M.Sc., F.C.S., M.I.Mech.E.

THE recent tendency in oilfield equipment has been to increase drilling speeds and, at the same time, to reach deeper depths than were formerly possible. The exceptional strain and hard usage of drilling machinery, consequent on deeper and faster drilling, has necessitated strengthening, and in many cases redesigning, various portions of the equipment.

As the production side of the industry is one where technology plays a more important part than pure science, any new departure necessitates experimental work of a practical character for its development with the result that we have still to look to the American fields for improvements in drilling and production methods generally.

In regard to derricks, the general tendency is to make these of stronger and stiffer design, with more rigid bracing, capable of withstanding the severe vibration to which they are now put, especially with rotatory work. The latest departures, with steel derricks, are to make the legs of a compound construction, having inside and outside angles at each corner, so that when drilling is completed the outside angles can be removed and re-erected on a new derrick elsewhere, leaving the remaining structure capable of handling pumping equipment; also to have the derrick galvanised; improvements in design whereby their lack of elasticity, as compared with wooden rigs, is offset by higher mechanical efficiency. There are several novel features in these rigs to draw attention. For example, modern practice is to enlarge the crankshaft in the centre to carry the bandwheel, the latter being

of steel construction throughout, crowned and made in sections for easy transport. The tug rim is of cast steel, with properly formed "V" grooves, which gives a much more efficient transmission of power than the old shallow grooves used on wooden tug rims.

The old method of friction drive to the sand reel has been superseded, in latest practice, by a chain-drive, motion being imparted to it by a cast steel sprocket mounted on the crankshaft, on roller bearings, which is connected by clutch to the band wheel hub. The sand reel itself is mounted as a separate unit on an extended framework of the rig and the reel is fitted with a band brake and friction clutch of the band type, both brake and clutch being operated by one lever from the derrick base, one movement throwing the hoisting motion into operation, the reverse motion declutching and throwing the band brake into operation.

An improvement in spool dividers on the all-steel bull and calf wheels has been noted, these being split and easily loosened and tightened, by means of the clamping bolts, from the edges of the rim; they are of strong cast-iron construction with smooth faces on both sides, the edges being well rounded.

The old type of wooden pitman, with primitive bushings for the crank pin, has given place to several improved types with quick detaching arrangements for the crank end. One type has a slightly tapered bush, with a bronze liner, mounted permanently on the crank pin and kept in place against the end of the journal by means of a ring washer: this bush has a groove for attachment of the spudding rope. To detach the pitman end from the crank pin, a locking pin is disengaged and a clamping plate is then lifted out of its grooves and the pitman pulled off the tapered sleeve, the operation taking but a few seconds. The pitman is a solid rod of forged steel, with screw adjustment at the top end to meet the level of the walking beam.

Recent improvements in crown blocks embody better methods of lubricating the sheave axles, the bearings being ring oiled, with ample sized oil-baths. The covers of the blocks, in addition to being bolted down, are hinged so that when the covers are open for inspection there are no loose parts to drop on men below. The blocks are fixed to the beams by hook bolts so that adjustment is easy. Manganese steel sheaves are the latest departure and, owing to their greater strength lightness and freedom from wear, are a considerable advantage.

Temper screws have been improved recently, being of sturdier design and of better engineering finish than the older ones. In one design the reins, of flat-bar section, are arranged so that they can be easily detached and removed when necessary, and the feed

is given by means of a ratchet handle which prevents the possibility of the screw running off.

The recent standardisation of cable and rotary tool joints by the American Petroleum Institute should prove of great advantage to users, and all purchasers of plant will insist, no doubt, on their suppliers working to these standards, when the new joints have been tried out on the fields and standard gauges issued. This will cause a certain amount of trouble with existing tools, for the time being, but field men will agree, in view of the troubles which have arisen in the past owing to the variation in joints produced by different manufacturers, that there should be one standard gauge only in the future.

Repeated troubles in the past with welded sinker bars and sinker bars made from rolled bar with upset ends have brought about the adoption of solidly made sinkers, forged down from the billet without weld. The same remarks apply to the weldless type of drilling jars, these having emerged from the experimental stage and have now attained a high degree of perfection; notwithstanding their comparatively high cost many fields engineers have satisfied themselves as to their superiority over the old type of jars as a result of their being forged from a special alloy steel, not suitable for welding, but better able to withstand shock and abrasion than ordinary steel; they have found that the number of fishing jobs, as the result of fatigue and consequent fracture, have been considerably reduced.

The "Parrot" rope knife is an improvement on the old type of double cutter knife, as the knives, instead of working within the barrel, are proud of the bottom face of the body and cut direct on to the top of the rope socket so that no projection of rope can interfere with a fishing tool. The cutters are also designed to just miss each other with the result that a clean positive cut is made of the line.

A useful tool of new design is the Kliewer casing hitch. It is a combination of two sets of slips, one inside, the other outside, with a split neck to run over a drilling line. It can be used to take hold of a rope socket neck or body, using the casing in which the tools are standing as a means of removing the tools from the hole; or where casing has parted, it can be used to help form a connection between the frozen and free portions by lowering a fishing string with an ordinary casing spear to engage the lower joints, when the casing hitch can take a hold of the rope socket and, at the same time, of the free pipe. By cutting the fishing line, a strain can then be taken on the pipe and transmitted to the frozen portion and, if freed, stripping is unnecessary.

Spiders are now manufactured with a lever lifting device connected to all the slips so that one man can hold them free or

engage them as required. The danger of dropping a slip down the cellar or uneven wedging is eliminated by this means.

The latest development in rotary practice is the make and break type of table, and in regard to the design of draw-works the tendency is towards heavier construction with the use of steel throughout; larger rope drums, three-speed drives for the drum, balancing devices to equalise the braking load on both brake drums and all lever connections arranged above the derrick floor for easy access.

Attempts have been made in America to increase rotary drilling speeds by running the table at a greater number of revolutions per minute, and at the same time allowing the fish tail bit to take a thinner cut. With a view to reaching speeds up to 250 r.p.m., as against the usual 80 to 100 r.p.m., it has become necessary to supersede the ordinary type of machine, with cone rollers under the table and bronze bushings on the pinion shaft, and to replace it with a table running on ball bearings in hardened steel race plates, the pinion shaft being mounted in steel roller bearings.

Both the ball bearings and the pinion shaft bearings are totally enclosed, thus being protected from mud and water, although able to retain ample lubrication. The teeth on the rotatory table are machine cut on a separate ring of special gear steel, which is afterwards shrunk on to the table.

The bevel pinion is also of special steel, so as to withstand the high speeds for which they are intended, and the whole assembly is balanced so well that the rotatory table will turn, when free, if a start is given to it by the pressure of one finger.

The principal feature of the modern rotary is the make and break device for utilising the power of the table in screwing up and unscrewing drill-pipe and casing. A special elevating spider with back-up post and table tongs are used for this purpose, and the machines are very easily changed from the make-up to the break-out position by raising or lowering the spider, at the same time giving it a quarter turn in either direction.

Deeper and faster drilling has brought with it the handling of very long and heavy strings of drill-pipe and casing and more attention has had to be given, consequently, to the hoisting apparatus generally.

The great friction on the brake rims caused by the weights to be handled and the speeds necessitated by considerable depths, has caused failure of the brake drums in some instances. Experiments have been made with the object of determining the most suitable materials for brake drums and cast-steel and pressed-steel rims and flanges were found to be unsuccessful, due to the fact that

small particles broke away and became embedded in the brake linings which quickly wore them out and impaired the efficiency of the braking surface.

The present practice appears to be to fit the draw-works with steel drums and flanges, but with cast-iron brake rims about 12 ins. wide. Cast-iron is known to give the best braking surface, as there is much less tendency for small particles of this metal to break away, and the width gives sufficient radiation surface to prevent the temperature increasing to such a point as to cause danger of fracture.

The three speeds now in use on up-to-date draw-works enable very heavy loads to be started with a minimum demand on the prime mover. The development in crown blocks and travelling blocks has been in the direction of employment of more suitable material, manganese steel sheaves, which have much greater wear resisting qualities than ordinary cast steel sheaves, now being in demand. These sheaves can be made to run in ball or roller bearings, grease being injected under pressure.

Safety devices have at last received attention and travelling blocks are now furnished with built in wire line guards, which render it impossible for any of the crew to become injured by getting a hand or arm pinched between line and sheaves; chain guards over the draw-works have also been installed.

It is becoming the practice to float long strings of casing into the hole, thus relieving the draw-works, derrick and other parts of the equipment from strain. For this purpose a back-pressure valve is screwed into the casing shoe in conjunction with a floating plug, and being made of light cast iron is easily drilled out. This valve can also be used for cementing, as it prevents any of the liquid cement coming back into the pipe, and when first lowered is held open by means of a dog to allow the water free passage. A slight tap on the valve spindle or, when cementing, an excess of pressure on the inside, opens the valve wider and a light spring draws the dog clear, when the valve will shut as soon as the pressure is relieved.

The practice of taking cores practically the whole way down in new territory is now becoming more common, and for this purpose core barrels have been designed which permit of a full gauge hole being drilled whilst taking the core. The core drill has four cutters dovetailed into the head and these are held in place by a saw-tooth core shoe which has a hollow taper threaded pin which enters the drill.

Two check valves, in case one is held open by the core, are provided to permit of any entrapped fluid escaping from the core barrel as the core gets longer and also to prevent the mud fluid entering the barrel instead of passing out between the cutters.

A method of feeling the way into an oilsand has been introduced in the Argentine field, where the combination system is used, by Mr. Campbell Hunter. When nearing the oil sand and cores are required, the cable tools are disconnected from the walking beam and inverted flush core tools are suspended. Whilst the drilling with these tools is not so fast as when used with the Fauck rig, nevertheless complete information, as to the formation being drilled through, is obtained, and this method has been found to be quicker and cheaper as the pieces of core are brought to the surface by the flow of water passing up the drill stem.

The recent tendency in the design of engines for drilling purposes is again towards more rigidity and stronger design. Considerable advance has been made in the design of petrol or paraffin driven engines, which will develop up to 100 b.h.p., and these are provided with a reversing pulley arrangement of strong construction.

With regard to oil production, one of the most interesting developments has been in the direction of long stroke pumping devices, the object being to give a longer stroke to the plunger or travelling valve at a slower speed. Another development in pumping deep wells is the introduction of the two-stage pump, which consists of one working barrel with valves at or near the bottom and another about half way up; the object being to raise the oil in two stages in order to minimise the strain on the lower pump, and also that sucker rods of smaller dimensions may be used for the lower section, thus considerably reducing the total weight to be operated at each stroke of the walking beam or bell crank.

No improvement appears to have been made in the method of imparting motion to idle parts, the old-fashioned dog clutch being used, and in rotary plant especially, constant clutching and declutching is still the cause of a tremendous amount of wear and tear on draw-works, engine and derrick.

The writer is indebted to Messrs. The Oil Well Engineering Co., Ltd., and Messrs. The National Supply Corporation for much of the information which is given in this paper.

Poland.

By Albert Millar, A.M.I.Mech.E.

The year 1924 was a critical one for the petroleum industry, due to several causes, the chief reasons being:—Stabilisation of currency, high taxation, increased cost of working due to a great extent to excessive import duties on drilling equipment, high railway tariffs and a drop in crude oil prices. In spite of these adverse conditions, there was an increase in the footage drilled as

well as in the production of crude oil and natural gas. The casing-head gasoline industry made good progress during 1924. By way of comparison statistics are given for the past five years :—

Year.	Ft. drilled.	No. of workmen.
1920	194,699 ..	12,040
1921	219,140 ..	12,683
1922	292,740 ..	13,730
1923	301,508 ..	14,003
1924	330,598 ..	10,947

At the end of 1924 there were 1,834 wells throughout Galicia producing oil, 141 producing gas only, 343 erecting or drilling, and 780 closed down temporarily.

CRUDE OIL PRODUCTION.

Year.	Drohobycz.	Jaslo.	Stanislow.	Total in brls.
1920 ..	4,971,970 ..	355,224 ..	179,438 ..	5,506,632
1921 ..	4,538,044 ..	365,234 ..	171,786 ..	5,075,064
1922 ..	4,538,263 ..	403,723 ..	192,334 ..	5,134,320
1923 ..	4,669,888 ..	410,174 ..	227,635 ..	5,307,697
1924 ..	4,847,588 ..	410,536 ..	291,564 ..	5,549,688

CRUDE OIL PRICES (BORYSLAW GRADE).

Year.	Average price per brl. in Zloty.
1921	7·78
1922	10·98
1923	12·23
1924	10·94

Taken on the basis of one zloty = 0·793 of 1s. (9¼d.).

NATURAL GAS PRODUCTION AND CASING-HEAD GASOLINE.

Year.	Production of gas, cu. ft.	Production of gasoline in galls.
1920 ..	14,303,707,000 ..	222,375
1921 ..	14,138,737,000 ..	247,986
1922 ..	14,245,121,000 ..	345,825
1923 ..	13,782,958,000 ..	878,087
1924 ..	15,468,217,000 ..	1,288,125

The amount of gas treated for gasoline was only 1,496,716,100 cu. ft.

The Daszawa gas well, situated near Stryj, which was drilled into production in the spring of 1924, is still producing the same quantity of gas under the same pressure as when it was first drilled in. A pipe-line 43 kilos. in length has been laid between Daszawa and Drohobycz for supplying the refineries there with cheap fuel. A further extension of this pipe-line to the town of Sambor is under construction. The Daszawa well is producing 4,800,000 cu. ft.

of gas per minute (approximately), and a second well is in course of drilling on the same property.

The crude oil worked up by Polish refineries during 1924 was 5,072,256 barrels, and the following quantities of products were manufactured :—

Gasoline	770,000 brls.	Paraffin ..	76,000,000 lb.
Kerosene ..	1,520,000 „	Asphalt ..	7,700 tons.
Gas oil	815,000 „	Vaseline ..	810,000 lb.
Lubricants ..	830,000 „	Coke	8,900 tons.

There are 38 refineries in Poland; of this number about 12 can each work up to about 7,500 barrels of crude monthly, eight have each a capacity of 22,000 barrels, and the seven largest have a refining capacity of 75,000 barrels each monthly. It is estimated that the total working capacity of all the Polish refineries is in the neighbourhood of 9,000,000 barrels per annum. The total number of workmen employed in the refining industry is 6,500. In 1924 about 75 per cent. of the crude oil produced belonged to companies who are both producers and refiners.

Home consumption during 1924 was 51 per cent. of the kerosene refined, 22 per cent. of the gasoline, 24 per cent. of the gas oil, 36 per cent. of lubricants, 24 per cent. of the paraffin, 90 per cent. of the vaseline and 18 per cent. of the asphalt, which works out per head of population 1·24 gals. of kerosene, 0·275 gals. gasoline, 0·325 gal. of gas oil, 0·5 gal. of lubricants. The value of the entire home consumption during 1924 amounted to £1,400,000.

Export.

Gasoline	665,000 brls.	Lubricants ..	500,000 brls.
Gas oil	600,000 „	Paraffin & candles	56,000,000 lb.
Kerosene	780,000 „	Semi-prod. ..	245,000 brls.

The value of the exports was £3,300,000.

The export of crude oil was prohibited, because the production is at present below the working capacity of the refineries. The prohibition will be lifted as soon as 4,500,000 barrels of stocks have accumulated. A by-law permits an export of 30 per cent. of the crude oil output from wells on new territories located at least two miles from an oilfield.

The Polish State own approximately 700,000 acres of oil lands, which they intend to lease out to private concerns.

During 1924 there was considerable drilling activity in the district of Bitkow-Pasieczna and Rypne in Eastern Galicia.

Drilling with cable tools made considerable progress during 1924, and have proved their superiority over the pole tool system.

France.

By J. A. LAUTIER.

Interior Régime for Petroleum.—The monopoly for purchases and importation of petroleum created at the request of the United States, with the view of insuring the working, during the war, of the "Interallied Petroleum Executive" gave place, in 1921, to a régime of controlled liberty; a régime which has been consolidated by the new law of January 10th, 1925.

This law permits of the exercises of competition. Sheltered by it, foreign companies may in all security make installations in France for the direct sale of their products. The State, on its part, seeks to favour a certain equilibrium between the Trusts, and to exercise a necessary control of the material which is of such importance to the life of the nation.

The most recent statistics show that the United States furnishes France with 77 per cent. of its supplies in petroleum, Mexico and Rumania coming next with 4.8 and 4.7 per cent. respectively. The supplies coming from Russia shortly will contribute to make up the supplies for France to the pre-war condition.

The Exterior Policy for Petroleum.—Being a great consumer of petroleum, France cannot find absolute security for its supplies in time of war, unless she can hold large stocks, or possess exploitations of her own soil; or unless she can, as a further measure, find substitutes for them by products of her own ground.

For any surplus it will be necessary to import from abroad, and by sea, which means that supplies of petroleum for the country will be a problem of "freedom of the seas."

In this way, however, France can only have a relative security, based upon alliances and a judicious geographical sharing of the important sources of petroleum controlled by French capital.

By the San Remo Agreement (April 24th, 1920) the British Government recognised the right of France to a 25 per cent. participation in the company which should eventually exploit the oilfields of Mesopotamia.

By the convention with Poland (1922) France was able to obtain a contract for favourable conditions of exploitation for her own account in Galicia.

In Rumania French capital has acquired equality with the British capital in the control of the most important producing companies.

Prospecting in French Territory and the Colonies.—With a view to encouraging private enterprise in prospections in the country, the French Parliament, by a law of 16th December, 1922, instituted Exclusive Permits for research work, with rules for the immediate

temporary occupation of territory, and the right for the successful prospector to obtain the concession ultimately. This law, inspired by the most modern necessities, gives to the prospectors guarantees and facilities which were previously lacking.

At the present moment the search for petroleum by private initiative is developing in various parts—the Landes, Basses Pyrénées, Pérénées Orientales, Aude, Herault, Var, Ain (where the discovery of natural gas was made), Haute Savoie, Puy-de-Dôme, Gironde, Charente Inférieure, and Eure and Loir. Up to the 10th of February, 1925, 14 exclusive permits have been granted, and 38 other demands are under examination.

In order to show a good example, the State itself undertook research work in August, 1924, at Gabian (Herault), which resulted in the discovery of petroleum on the 6th of November at very little depth. This was the first French petroleum well commercially exploitable, excepting, naturally, the Pechelbronn mines in Alsace. Following this discovery 17 fresh applications for search permits were made immediately afterwards for grounds in the vicinity of the State workings at Gabian.

It may be mentioned in addition that the Pechelbronn Company has been exploring in a territory which up to the present had not been worked upon, and made the discovery in March, 1925, of a new petroleum stratum at a depth of 450 metres, which has been giving out petroleum regularly at the rate of 5 tons per day.

The company is constantly developing the method of exploiting by drifts or "galleries," introduced by M. Paul de Chambrier. At the commencement of 1925, over twenty-one miles of underground tunnelling had been effected, which assured an annual output of about 35,000 tons of crude-oil, representing 40 per cent. of the total production.

Similar efforts to those which are being actively pushed in France itself are being planned for Algeria, Morocco, Syria, Madagascar and Indo-China.

The Technics of Exploitation and Use of Petroleum.—The following table of importation into France of the principal petroleum products, during the years 1922, 1923 and 1924, shows a regular increase in tonnage of 16 to 18 per cent. per annum :—

Products.	1922. Quantity in thousands of tons.	1922. Value in millions of francs.	1923. Quantity in thousands of tons.	1923. Value in millions of francs.	1924. Quantity in thousands of tons.	1924. Value in millions of francs.
Kerosene ..	311	156	297	153	305	196
Motor spirit ..	552	591	728	835	859	1016
Lubricants ..	187	174	204	216	242	305
Fuel oil ..	77	21	113	33	156	58
	1127	942	1342	1237	1562	1575

Without wanting in the least to hinder the importation of products essential for its economic activity, France wants to diminish its needs. It is thus, for example, that the systematic electrification of the country should lead to a radical diminution of the importation of petroleum.

Concerning combustible oils and lubricants, the researches have in view the improvement in the technics of exploitation, and development of substitutes.

By the latest installations of refining plant at Pechelbronn, the production of lubricants from the Alsatian Mines will shortly be able to cover a large part of the country's needs. In addition, the laboratory of Strasburg is examining methods of refining which will permit of extracting from the Gabian oil more than 50 per cent. of light essences.

On another side of the question, the Office National of Inventions, and the Laboratory of the Arts and Métiers College, have recently perfected a new motor—the Andreau Motor—which embodies several improvements of considerable value from the point of view of the consumption of spirit and the power resulting.

In order to specially facilitate efforts of this kind a National Station for Trials of Motors is going to be erected at Bellevue (near Versailles).

The Policy for Substitute of Petroleum.—The substitution of native carburants in the place of imported products is being seriously examined by the Carbonisation Committee, various sections of the Scientific Committee for Petroleum, and a number of professors specially interested in the problem.

The competition of vehicles with gas engines organised during recent years have raised considerable emulation amongst the French constructors. In the 1923 competitions, especially, considerable progress in technic was apparent, touching particularly the increase of power by increasing the compression volumetric, and, above all, by purifying the gas. The competitions in September and October, 1925, will probably see these interesting experiments perfected.

The technic of alcohol as a carburant is another direction in which France is engaged. Thanks to the work of Messrs. Daniel Berthelot, Georges Baume, and several other engineers and scientific men, this technic is to-day perfected. The use of 50 per cent. of spirit and 50 per cent. of alcohol-absolute requires no modification of importance, nor changes in the motors for spirit. If the consumption is a trifle higher, and the starting rather more difficult in cold weather, the motor gains by easier working and faster speeds on the hills.

The movement of opinion in favour of adopting a "carburant national" has been prolific in discoveries: the finding of properties in "tiers-solvants"; the inventions of Messrs. Loriette, Guenot,

and Delamar for the preparation of the alcohol-absolute; the studies of Messrs. Dumanois and Schwers on the action of combustion of carburants, etc.

Up to the present the available quantities of alcohol have only been sufficient for the supply of carburant national of the lorries for the Army, the Paris Omnibuses, and the heavy cars of a certain number of enterprises in the Paris district and the South of France. In consequence of its higher "prix de revient" the alcohol is produced in insufficient quantities, and the only way out of the difficulty has been to "drown" the alcohol of beetroot, which is the alcohol now used, in other kinds of alcohol more abundant and cheaper—such as that produced from cellulose, synthetic alcohol, or alcohol from the colonies.

It is in this direction that the Office National of Liquid Combustibles is going to extend its efforts, and in which work it will find itself successful because of the advances in researches connected with the synthesis of carburants. In 1924, in fact, a large industrial laboratory for synthetic work, was erected at Villers-St.-Paul (near Creil), at which important results have already been obtained, and which, together with the results acquired by Mr. Georges Patart and the engineers in the military service, will permit France to overtake the advance made in this matter by other countries. In particular, the systematic examination of catalysers has led to the transformation of mixtures of carbonic oxide, and hydrogen in methanyl, with a chemical resultant of 100 per cent., at temperatures and fusions which do not appear to belong to industrial possibilities.

Training of Technicians.—The year 1924 saw the foundation at Strasburg of a "National School for Petroleum," which counts amongst its teaching personnel scientific men such as Messrs. Friedel, Muller, Gault and Paul de Chambrier.

The "Ecole Supérieure d'Aéronautique et de Constructions Mécanique de Paris," which was created some years ago, is just now opening a new section for teaching matters of petroleum, its employment, and the technic of internal combustion motors.

In the domain of researches the Scientific Committee for Petroleum and Liquid Combustibles, which has just been reorganised, is now grouping together all the scientific men which France counts in glorious prestige—Sabatier, the inventor of Catalysis, Haller, Le Chatelier, Termier, Moureu, Koenigs, Charpy Viala, Daniel Berthelot, Behal, and many others.

In association with the Scientific Committee for Petroleum, and supported by it, there are laboratories working upon the problems already indicated, at Paris, Toulouse, Strasburg, Villers-Saint-Paul, Montpellier, Douai, Bellevue, and Villacoublay. So that France has already the basis of a technical formation which will embrace the research, production, treatment and employment of petroleum.

Installations for Reception, Distribution, and Transport.—Extensive new installations have been made, or are in construction, for the reception of large steamers at Havre, Cherbourg, Donges, La Pallice, Pauillac, Port-St.-Louis-du-Rhône, etc. . . . Whereas six years ago France had only reservoirs for 650,000 cubic metres of petroleum products, which was clearly insufficient for the needs, to-day installations have a capacity sufficient for 1,900,000 cubic metres; suitable measures also are being taken for relieving the congestion at the ports and improving the distribution of the stocks to the interior of the country. The continued intensive increase in the employment of automatic distributing apparatus for spirit will greatly facilitate the execution of the improvements projected.

As for the French Tank Steamers for petroleum, which did not exceed a total of 30,000 tons dead weight in 1918, they represented, at the end of 1924, a total of 217,000 tons.

Trinidad.

By A. P. Catherall, B.Sc., M.I.Min.E., A.M.Inst.M.M. (Inspector of Mines).

Steady progress was made during the year with the result that the production of crude oil was 4,056,612 barrels compared with 3,050,872 barrels for 1923. This increase of production has been due to the development of already proven fields, and not to the discovery of new areas, as by far the greater part of the output of crude oil is still obtained from the Fyzabad—Morne L'Enfer—La Brea districts.

The exports of petroleum products show a large increase compared with last year, the figures being 113,000,000 gallons as against 85,000,000 gallons for the year 1923.

It is of great interest to note that for the first time in the history of the Colony the exports of petroleum products were greater in value than the products of any other industry and formed over 30 per cent. of the total exports of the Colony. In 1924 petroleum products to the value of £1,367,160 were exported compared with £1,276,850 for sugar, molasses and rum and £1,165,816 for cocoa. To realise the increase of this industry we have only to compare the figures of ten years ago; in 1914 the value of petroleum products exported was £67,345 and formed less than 3 per cent. of the total exports. The major portion of the export trade is in the form of oil fuel, of which a large part is shipped to the Admiralty under contract.

The following table will show the number of feet drilled and the quantity of oil produced during 1924 compared with the years 1922 and 1923 :—

Year ended December 31, 1922.		Year ended December 31, 1923.		Year ended December 31, 1924.	
Feet drilled.	Oil won Brls. of 35 galls.	Feet drilled.	Oil won Brls. of 35 galls.	Feet drilled.	Oil won Brls. of 35 galls.
135,870	2,444,752	145,801	3,050,872	151,892	4,056,612

The total number of wells drilled in the Colony to December 31st, 1924, is 928; during the year under review 110 new drills were drilled, an increase of 2 compared with 1923. In 80 of these wells oil was struck.

No new shipping or refining depots have been constructed during the past year, though some additions have been made to existing installations. There are now four outlets for the shipping of petroleum products, viz. :—

Claxton Bay	Trinidad Central Oilfields, Ltd.
Pointe-a-Pierre	Trinidad Leaseholds, Ltd.
Brighton..	Trinidad Lake Petroleum Company, Ltd.
Point Fortin	United British Refineries. Ltd.

Each of these companies also possesses facilities for the refining of crude oil.

Toward the end of 1923 a branch of the Mines Department was opened at San Fernando to deal with conservation of oil and gas and other problems of the petroleum industry with which this department is concerned. In this office a considerable amount of original research has been undertaken by the officers stationed there (one a petroleum engineer and the other the Government Geologist). The peg model room, in which models of the underground conditions existing in the various oilfields are constructed by the officers in charge, is shown in figure 1.

A statement showing the operations of the various companies is appended, together with a series of curves depicting the progress of the petroleum industry during the past few years.

Companies.	Remarks.
Trinidad Leaseholds, Limited.	Largest producing company in the colony. Large purchases of crude oil from other companies are made and refined at Pointe-a-Pierre. Very great activity has been shown during the past year, and the field on Crown lands at Fyzabad greatly extended. A well was also drilled on private lands at Guayaguayare without striking oil.
United British West Indies Petroleum Syndicate, Limited.	No drilling except at Los Bajos.
United British Oilfields of Trinidad, Limited.	Drilling continued at Point Fortin and on Parry lands area.
Trinidad Central Oilfields, Limited.	Drilling was continued on the Tabaquite field during the whole of the year and a fair production obtained. A number of test wells were also drilled in new districts.

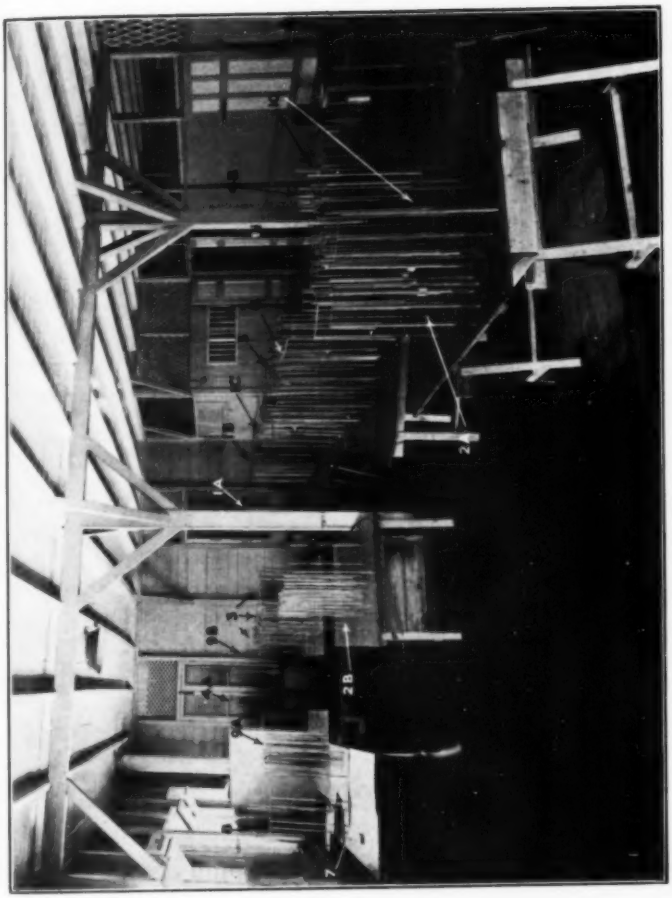
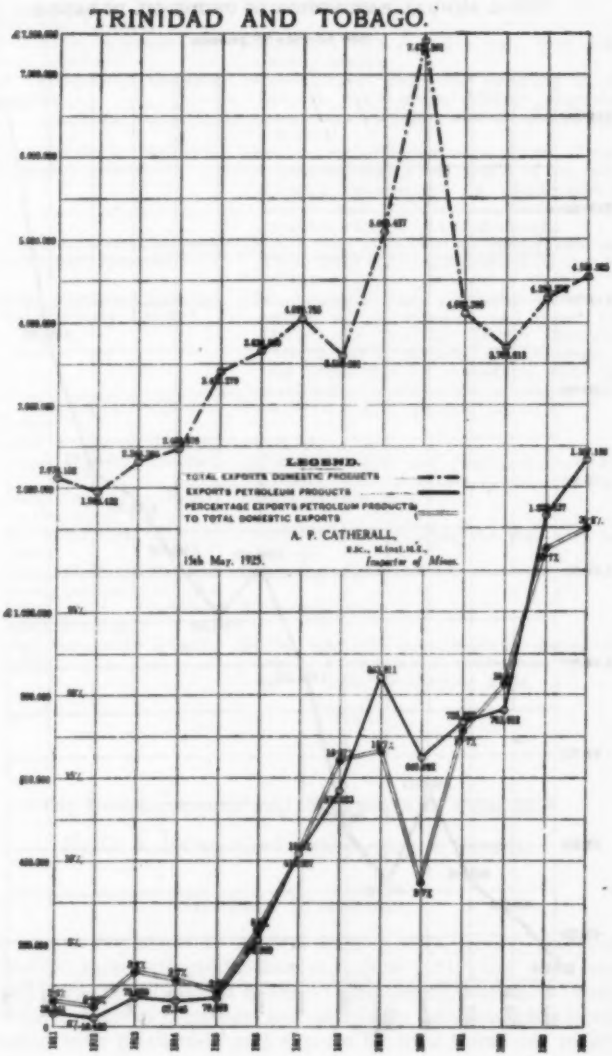


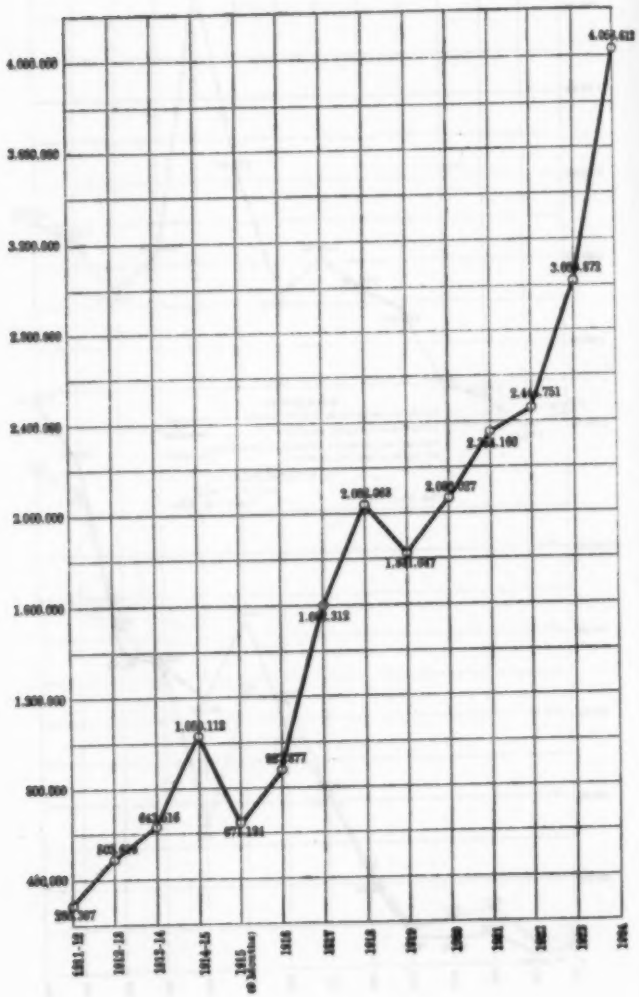
Fig. 1.

UNIV. OF MICH.


TRINIDAD AND TOBAGO.
LEGEND.
TOTAL EXPORTS DOMESTIC PRODUCTS
EXPORTS PETROLEUM PRODUCTS
PERCENTAGE EXPORTS PETROLEUM PRODUCTS TO TOTAL DOMESTIC EXPORTS
A. P. CATHERALL,
15th May, 1925.
Inspector of Mines.

TOTAL ANNUAL PRODUCTION OF CRUDE OIL IN BARRELS.

One barrel=35 gallons



Companies.	Remarks.
Trinidad Lake Petroleum Company, Limited.	Producing only.
Petroleum Development Company, Limited.	Drilling on Lots 1 and 4 with very satisfactory results.
Apex (Trinidad) Oilfields, Limited.	Second largest producing company in the colony. Very active drilling programme has been undertaken and the field largely extended.
Kern Trinidad Oilfields, Limited.	Development of Perseverance Estate, Guapo, continued during the whole of the year. Drilling commenced on Boodhoodsingh Estate, near La Brea, in January and continued to the end of the year.
General Petroleum Company of Trinidad, Limited.	Drilling was carried out on the Fyzabad and Penal fields with a fair production from the former.
Trinidad Petroleum Development Company, Limited.	This company was originally under the control of S. Pearson and Sons, Ltd. During the year the British Controlled Oilfields, Ltd., acquired the interests of this firm. Drilling operations were suspended for a great portion of the period.
New Naparima Oilfields, Limited.	Shut down during whole of period.
Trinidad Freeholds, Limited	Producing only.
Petroleum Options, Limited.	Drilled one well and produced from two others.
Trinidad Friendship Petroleum Company, Limited.	Producing only.
British Controlled Oilfields, Limited.	Continued drilling during the year with fair success.
Trinidad Oil Producing and Refining Company, Limited.	Producing only.
Transvaal and Rhodesian Estates, Limited.	Producing only.
Trinidad Esmeralda Estates, Limited.	Drilled one well unsuccessfully during the year. A very small production was obtained from the existing wells.

Oil Developments and Prospects in Canada.*

By G. S. Hume, Geological Survey of Canada.

General Statement.

The oil developments in Alberta during 1924, giving prospects of possible increased production, are quite gratifying when considered from the standpoint of the oil situation in Canada. During 1923 the imports of petroleum and petroleum products into Canada exceeded both production and exports by over thirty-one million

* Published with the permission of the Director, Geological Survey.

dollars, the production being less than 1½ per cent. of the consumption. Such a condition is encouraging for development, and drilling during 1924 has shown new possibilities for the Foothills area that may be of great importance. In the Plains area in the Wainwright field of Eastern Central Alberta another oil well has been drilled, while other wells in the same general area have shown possibilities of large gasfields. In Southern Alberta the development of the Foremost Gasfield is a feature of the greatest satisfaction, particularly to those centres of population who were being supplied with gas from the declining Bow Is. Gasfield.

In Ontario and New Brunswick the situation is less encouraging. The Ontario oilfields long ago passed the peak of production, and for many years there has been a general decline, although the opening up of new fields from time to time gave temporary increases. There are still some untested areas where new production might be secured, but the prospects for developments leading to a large increase in production are not considered favourable, and it is probable the gradual decline will continue. In New Brunswick, on the other hand, there is some reason to hope that production might be considerably increased, but the development depends on the financial considerations of whether the results are likely to justify the expenditure.

Turner Valley or Sheep River Field.

This area, also known as the Okotoks field, lies about 40 miles south-west of Calgary, and is the field that caused the Calgary oil boom of ten years ago. The structure[1] of the field is an anticline, the crest of which has been eroded, forming a valley up to two miles in width and bounded on the flanks by parallel ridges trending in a north-west and south-east direction. West of the oilfield is the faulted and much broken area of the Foothills, while to the east the anticline is also cut off by a fault with the strata dipping as high as 70°. East of this fault the beds dip eastward into the great Alberta syncline, in most parts of which the Cretaceous is so deeply buried beneath Tertiary deposits that it is below the reach of the drill.

Drilling began in 1913, and since that time twenty or thirty wells have been drilled in this field and the surrounding territory. Production has been confined to the anticlinal structure, and consists of only a small amount of crude oil, almost the total production varying from five to eleven thousand barrels per year being obtained from the treatment of wet gas in the Royalite Company's absorption plant. The oil that is obtained is of very

[1] S. E. Slipper, Memoir 122, Geological Survey, Canada, 1921.

light gravity, and operators in general have believed that it is a condensation product from a deeper reservoir.[2] To test out this theory the Royalite Co., a subsidiary of the Imperial Oil Co., began a deep test known as Royalite No. 4 well in 1922, and completed it at 3740 ft. last autumn with a flow of very wet gas estimated at twenty to thirty million cubic feet per day from limestones of Carboniferous age. The well "came in" without warning, and blew the drilling tools from the bottom of the hole to the bottom of the 6¼ in. casing at 3450 ft. There the tools wedged and broke the drilling cable. A fishing job resulted in the loss of a string of fishing tools. An attempt was then made to shut in the well. The 6¼ in. casing was clamped to the 8¼ in. casing, and a three thousand pound valve placed on the top. When the valve was closed an enormous pressure soon accumulated, resulting in the casing with the attached valve being thrust through the top of the derrick. On a sudden release of pressure the whole thing came down with a crash. In an attempt to repair the well the gas again burst forth, and it is presumed a stone thrown out by the gas struck a spark which ignited the flow. The fire was extinguished, but the well is not yet completely under control. The gas has been piped about a mile south of the well, and from the pipe line by "drips" between two and three hundred barrels per day of 70° Baume oil are being obtained. It is understood the amount of gas going through the pipe-line is much less than the capacity of the well. At present the gas is not being used, as it contains sulphur and is objectionable for domestic consumption. It is expected that the gas will be treated in the Royalite Company's absorption plant when satisfactory arrangements can be made, and when this can be done the daily recovery of oil will be increased.

The significant feature of this well, aside from its great value, is the fact that a new gas and oil horizon—the Carboniferous—has been tapped. This not only opens up fine possibilities for further development in the Sheep River field, but also gives much encouragement to try to reach this horizon in other parts of the Foothills. The Royalite well is located on the crest of the anticline, so that it is possible wells drilled off the crest will obtain less gas and more oil, but such wells off the crest must be prepared to drill deeper than the Royalite No. 4.

Much trouble has been experienced in drilling the Sheep River field because of the steep dip of the strata in combination with the alternation of hard and soft beds. This is a condition that has almost invariably led to crooked holes, and fishing jobs in the wells have been the rule rather than the exception. In view of

[2] *Imperial Oil Review*, November, 1924.

the present development, however, it would appear from the volume and character of the gas that a large reservoir of oil and gas exists in the Carboniferous limestone, and no doubt further deep drilling will be undertaken. Up to the present the main production in this field has been from the Kootenay, but both oil and gas have been obtained from the overlying so-called "Dakota" sands.

The Wainwright-Irma Area, Eastern Central Alberta.

In Central Alberta the eastern flank of the great Alberta syncline, previously mentioned, brings the lower Cretaceous strata within reach of the drill, and the dip of the strata flattens out to give the terrace structure of the Wainwright-Irma field. During the summer of 1924 a geological survey party under the writer's direction studied part of this terrace structure, and by accurate levelling in connection with studies on sedimentation found that although the regional dip of the terrace is a dip of only a few feet to the mile in a south-westerly direction, there are a number of departures from this where the dip is in the opposite direction, thus giving small folds.

It will be recalled that British Petroleums, Ltd., "brought in" their No. 2 well as an oil well in the Fall of 1923. This stimulated drilling activity, and during 1924 a number of wells were started. Of these three have been completed; No. 4 British Petroleums, situated close to No. 2 well, is an oil well; No. 3 British Petroleums, situated one mile south-east, gave a show of oil and gas, but so far is not a producing well, although further attempts are to be made to bring it in; and No. 1 Maple Leaf well, seven miles south-west of British Petroleums No. 2 well, as now completed, is a gas well. An oil sand below the gas sand of Maple Leaf well is reported to have been penetrated but has not yet been tested. Operations have now ceased for the winter but will be resumed in the spring. About a mile east of Maple Leaf No. 1 well the Imperial Oil Co. drilled their Fabyan No. 1 well in 1923, with the result that about 10,000,000 cu. ft. of gas per day and some heavy oil was obtained. No. 1 Maple Leaf well is down the dip from Imperial (Fabyan) No. 1 well, and if oil is present in this locality the Maple Leaf well is favourably located to strike it.

The work of the Geological Survey led to the discovery of a fold at British Petroleums Nos. 2 and 4 wells, and the oil in these two wells is undoubtedly related to this fold. The fold is unsymmetrical, the western flank having a dip of only a few feet to the mile in a south-westerly direction, while the eastern flank has a north-easterly dip of about 40 ft. in half a mile or a little less than one degree. In view of the fact that this small fold has evidently

been the controlling factor in the accumulation of oil in this particular place, it is expected further efforts will be made to locate other folds.

In No. 2 British Petroleums well a thickness of 17 ft. (2019 ft. to 2036 ft.) of oil sand was drilled, but "bottom" water was encountered, and consequently precautions were taken to avoid this in No. 4 well. A core of the sand was taken, and at a depth of about 10 ft. in the sand a hard parting or "break" was found, at which drilling was stopped. No. 4 well is thus in shape to produce oil without the water troubles which are present in No. 2 well. The capacity of No. 4 well is unknown, but at the time the well "came in" on September 18th, oil rose in the 8 in. casing to within 50 ft. of the top, thus giving almost 2000 ft. of oil in the well. A 2 in. flow-line was then placed in the well, and the top of the 8 in. casing closed off, with the result that oil began almost at once to flow through the flow-line at the rate of about 25 barrels per day. The flow has decreased somewhat from the initial flow, and it is understood it is the intention of the company to pump the well. The oil in No. 4 well is from the same sand that is productive in No. 2 well, and is much the same in quality, being an asphaltic base oil of about 14° Baume. As far as can be told the oil is from sands in the Colorado group of rocks.

In No. 3 British Petroleums well drilling was carried considerably deeper than in Nos. 2 and 4 wells, and lower sands, probably the equivalents of the so-called "Dakota" beds, were encountered. It is reported that these gave a showing of higher gravity oil than in the other wells, but salt water was present, and has not been shut off. Since the sands in the basal Cretaceous beds provide the reservoir rocks for any oil that may be present, their thickness is a matter of great importance. The Imperial (Fabyan) No. 1 well was drilled through the Cretaceous into the underlying Devonian, the Carboniferous being absent here. Thus the thickness of the basal Cretaceous sands is known in a general way, although some variations are to be expected due to lensing of the sands. The thickness is many times less than in the McMurray area, Athabaska river sections, 250 miles to the north, where both the lower Cretaceous beds—the tar sands—and the Devonian are exposed. If it may be assumed that the basal Cretaceous sands thicken to the north, then it is obvious favourable structures located north of the Wainwright area will also be favourable locations to test with the drill. The discovery of such favourable structures or anticlines, if such exist, is a matter for detailed geological work in connection with accurate levelling, since only by this method small dips, such as are to be expected, can be detected. Levelling can be carried along some hard beds of sandstones to the best advantage, since these form the majority

of the outcrops, but care must be taken to note lateral changes in sedimentation since the sandstones belong to non-marine formations and show some lateral variation. Only a very small part of the area north of Wainwright has been so studied, but from reconnaissance work it is known there are a number of places where the regional dip is reversed, and it is possible with detailed work folds favourable for oil accumulation may be outlined.

Southern Alberta.

Recent drilling in Southern Alberta has been stimulated by developments in the Kevin-Sunburst field of Montana close to the International boundary. The Imperial Rogers well drilled on Sec. 29, Tp. 1, R. 11 W. of 4th Meridian, "came in" as a gas well with an open flow of 25,000,000 cu. ft. per day, and under a rock pressure reported at 945 pounds from sands of Kootenay age. Drilling was continued in the hope that oil would be found in the Ellis formation of Jurassic age, since this is one of the productive horizons of the Kevin-Sunburst field, but has been discontinued. According to work done for the Geological Survey by M. Y. Williams, of the University of British Columbia, the Imperial Rogers well is on a structure favourable for gas and oil accumulation, and there is thus at least the probability of a large gasfield in this area.

The new Foremost Gasfield being developed by the Canadian Natural Gas, Light, Heat and Power Co., Ltd., is 26 miles north and slightly east of the Rogers Imperial well. The last well drilled, No. 4, is reported to have obtained nearly 23,000,000 cu. ft. of gas from three sands in the Colorado group of rocks, the lowest sand giving a production of nearly 14,500,000 cu. ft. The four producing wells have now been connected with the Calgary pipeline, and are supplying Calgary and other centres. The structure is a broad dome, and the possibilities for an extensive gasfield are good.

Fort Norman Area, Mackenzie District, N.W.T.

The Imperial Oil Co., during 1924, started another well near their No. 1 Discovery well, which is the only well in this area containing oil, although two others were drilled. During the past summer this new well was carried down 975 ft., and oil was encountered at 122 ft., 792 ft. and 895 ft., the last amounting when struck to about 25 barrels per day, but decreasing to possibly 2 or 3 barrels at the time the well was shut in at 895 ft. It is the intention of the company to continue drilling this well next summer, a test considerably deeper than No. 1 Discovery well being contemplated.

Ontario.

In Middleton tp., Norfolk County, south of the town of Tilsonburg, a new gas well with an open flow of 600,000 cu. ft. has recently been drilled. The extent of the gasfield that is likely to be opened up due to this discovery is unknown.

For some years the Dominion Government has paid a bounty of 1½ cents. per imperial gallon on crude oil produced in Canada. On July 1st, 1924, half of this bounty was dropped, and it is the intention to discontinue the other half on July 1st, 1925. For some years Ontario has shown a gradual decline in oil production, and many of the producing wells have declined to less than a barrel per day. It is anticipated that the removal of the bounty will have the effect of causing a marked decline, but for the present this has been partly offset by the Imperial Oil Company, which buys the oil for the Sarnia refinery, advancing the price of oil to Ontario producers by 25 cents. per barrel, an amount practically equivalent to the reduction in the bounty.

New Brunswick.

The production of New Brunswick comes from the Stony Creek field, which is totally under the control of one company, the New Brunswick Gas and Oilfields, Ltd. It is understood that new developments during the past year have shown possibilities of not only considerably increasing the production but also of extending the field. However, it is probable that developments in this field, as in Ontario, will be greatly affected by the removal of the Government bounty, and the future of the field will depend on whether the company considers further exploration likely to be profitable without the bounty.

Western Canada.

By Stanley J. Davies, M.C., A.R.S.M., F.G.S.

The supply of oil in the British Empire has been a source of discussion for many years, and recent events in Western Canada have changed very definitely the proofs in regard to the supply of oil in Canada.

A brief history of a well known as Royalite No. 4, situated in the Turner Valley, thirty miles south-west of Calgary, Alberta, will perhaps be of interest.

This well was drilled by the Royalite Oil Co., Ltd., a subsidiary of the Imperial Co., Ltd. The latter for several years have had a

very extensive and expensive drilling campaign in progress, attempting to prove the extent of natural gas and oil possibilities in Canada.

No. 4 Royalite was commenced September, 1922, and drilling proceeded with cable tools until November, 1923, when at 2871 feet a flow of gas of 7,000,000 cu. ft. was encountered. The well was shut down until May, 1924, when drilling was resumed.

8¼ in. casing was set at 3,053 ft., and the gas encountered at 2,871 ft. was effectively shut off.

Drilling proceeded, and at 3,440 ft. a limestone was encountered. As this was a new feature in the territory of Southern Alberta, drilling was continued with renewed hope, 6¼ in. casing was set at 3,450 ft. and, in a very hard limestone, drilling continued with an open hole.

At 3,740 ft., when hope was beginning to fail, a very strong flow of gas was struck. Very suddenly the tools were shot up into the 6¼ in. casing and stuck at 3,450 ft. This was on October 14th, 1924. The drilling cable was soon cut, and the well was flowing on the morning of October 15th, 1924, at the rate of 21,500,000 cu. ft. a day.

The flow of gas then diminished and the drillers attempted to fish out the lost tools. Very suddenly the gas flow again commenced and again cut the wire line, leaving the fishing tools in the hole.

A 2,000 lb. valve was attached to the 6¼ in. casing, and it was decided to close the well in. It was observed that the pressure rose in 1 minute to 200 lbs., 2 minutes 400 lbs., 3 minutes 600 lbs., and continued to 1,150 lbs. This pressure was the last read by the crew. In twenty minutes the 6¼ in. and 8¼ in. casing commenced to rise into the derrick and, on reaching the crown block, the gas escaped on the outside of the casing and the 8¼ in. casing subsided, leaving the 6¼ in. casing up some 30 ft. in the air. The well almost immediately caught fire, this was on November 9th, 1924. The fire was extinguished by use of steam on November 20th. The reflection of the blaze could be easily seen at night in Calgary, some thirty miles distant.

The gas was tested and the gasoline content showed one quarter of a gallon per 1,000 cu. ft, and due to expansion of the gas the temperature at the well mouth was reduced to 22°F.

The well was connected up to five drip lines, and in a few days the amount of gasoline obtained increased to 300 Imperial barrels per day.

This amount has been slightly increasing, a certain amount of a light yellow oil being carried out of the hole with the gas. This oil has a specific gravity of 0·719.

At the present date the oil has a specific gravity of 0·700, and the production continues to be in excess of 300 Imperial barrels daily.

The gas contains 110 grains per 100 cu. ft. of Hydrogen Sulphide gas.

A series of Smith gas and oil traps have been erected now, and a pressure of 600 lbs. is being maintained on the well.

The gasoline is transported by motor truck fifteen miles to Okotoks, Alberta, and there shipped to an Imperial Oil Refinery at Calgary. At the present time this single well is producing one-third of the total amount of gasoline consumed in the Province of Alberta.

An important point of interest in this well is the fact that this production is coming from a limestone of very probable Devonian age, and for purpose of correlation with Montana is very probably the Madison Limestone. At the present time we are not aware of the presence of any Carboniferous rocks in Southern Alberta.

We may now generalize in regard to Western Canada.

The Fort Norman wells, in the McKenzie River area, have been very adequately described by Dr. Bosworth and rocks are Devonian in age. The tar sands in Northern Alberta are Cretaceous in age and immediately overlie Devonian Limestone.

We have now proved the existence of oil in Devonian Limestone in Southern Alberta. It is probable that most of the oil and gas in Western Canada actually originates from Devonian sources and the long list of failures to secure commercial oil wells in Western Canada has been due to the depth at which the oil has been located.

It has been estimated that up-to-date Royalite No. 4 has produced oil of a value of $200,000, without placing any value on the gas. Gasoline retails here for 37 cents. a gallon.

Another well adds confirmation to the proofs of the Turner Valley area, the McLeod Well, near Royalite No. 4, was brought in at 2,400 ft. in October, 1924, and produces from Dakota sands around 30 barrels a day of 0·840 oil. The well is capable of greater production, but transporation facilities are now lacking. This well has been producing some four months.

Royalite Wells No. 1 and 2 have been producing gasoline gas for some ten years and their production has been maintained very consistently.

The very great interest that Royalite Well No. 4 has aroused in United States and Canada has meant that a number of companies are preparing to drill in Turner Valley this year. The Royalite Co. have brought two rotary rigs into the field for the drilling of two new wells.

Argentina.

By CAMPBELL M. HUNTER, M.A., A.M.Inst.C.E., F.R.G.S., F.G.S.

SUBSTANTIAL progress was again recorded by the Argentine oil industry during 1924. Not only did the production of the Government show a marked increase over that for the preceding year, but the returns of the independent companies also disclosed steady improvement.

The following table, based on published returns of the Government and different producing companies during 1924, is unfortunately incomplete, since final figures are not in every case available, but the estimate of 663,550 tons for the gross output of the Republic will, it is believed, be found nearer the mark than that of 549,100 tons given by the American Petroleum Institute:—

	1924. Metric tons.	1923. Metric tons.
Government—		
Comodoro Rivadavia	467,000E ..	408,139
Plaza Huincul	9,500E ..	6,899
Cia. Ferrocarrilera de Petroleo	60,273 ..	35,714
"Astra"	90,537 ..	80,223
Cia. Industriel y Comercial de Petroleo (Anglo-Persian)	28,000E ..	?
Cia. de Petroleo de Comodoro Rivadavia ..	2,000E ..	3,552
Sociedad Petroleo de Challaco	6,000E ..	450E
Argentine Oilfields, Ltd.	240 ..	—
Total, metric tons	663,550 ..	534,977

E = Estimated.

During the period under review, the Government followed up with uniform success the productive pool which was first struck by well No. 128. This pool was extended 4 km. to the westward by the Cia. Industriel y Comercial, the Argentine operating company of the Anglo-Persian Oil Company, whose well No. 13 was reported to be one of the most productive ever struck in the Comodoro Rivadavia area. This success led the Government to drill offset wells, all of which proved highly productive. The satisfactory results following on the impetus given by the Government in 1923 to its drilling operations at Comodoro Rivadavia led to plans and estimates being drawn up for a National Refinery at La Plata, with an initial throughput capacity of 2000 tons a day, capable of further expansion. The contract for this refinery was placed in the United States, completion being promised before the end of 1925.

Further to the northward, the Cia. Ferrocarrilera de Petreoleo continued their previous year's success in the north of their property, every well coming in as a gusher. Similarly, the "Astra's" drilling resulted in an increased production. During the year the same company completed its loading arrangements at Caleta Cordoba, which were availed of by the other principal producing companies in the district, thereby relieving the congestion at the Government pier.

Prospecting operations were continued by the Royal Dutch Company, the Eastern Petroleum and Finance Company, Comodoro Oil and Transport Company (Koster's interests), the Standard Oil Company of New Jersey, the French "Omnium" Company and the "Kinkelin" Syndicate. Gas under considerable pressure was struck by the Royal Dutch Company in their well No. 2 at Kilometre 27, along the Comodoro Rivadavia-Sarmiento Railway, and it is hoped that this will lead to the opening up of a new inland oilfield. Gas under high pressure was also encountered in the well Solano No. 1 by Mr. Juan Koster, and has led to the drilling of several other wells in that area. The exploratory work of the other companies did not disclose anything of importance, and it was generally understood that both the Standard Oil Company of New Jersey and the "Omnium" Company had decided to slow down their drilling programmes.

Increased interest was drawn to the high grade oilfields of Neuquen by the successful completion of well S. 1 by the Sociedad Petroleo de Challaco, immediately to the westward of the Government Reserve at Plaza Huincul. This well was brought in in December, 1923, with a natural production of 30 to 50 tons a day. During the whole of 1924 it continued to flow intermittently, the oil being of the same high quality as that produced on the Government Reserve. The favourable turn given to the Neuquen oilfields by this well led the Standard Oil Companies of New Jersey and California to reconsider their decision about withdrawing from the district, each company securing two cateos immediately adjoining the property of the Sociedad Petroleo de Challaco. The first well drilled by the Standard Oil Company of New Jersey struck an enormous flow of gas in a stratum corresponding with the gas stratum overlying the oil sand in the Sol well No. 1. The well unfortunately caught fire, and for a considerable time defied all efforts to control it. As soon as a new derrick has been erected, drilling is to be resumed. In the meantime, the closed in rock pressure of the gas amounts to 1000 lbs. per square inch.

The Government pursued their policy of prospecting rather than exploiting their reserve at Plaza Huincul; several good wells were brought in, and it was definitely established that the north flank of the Cerro Lotena-Plaza Huincul Anticline was more

productive than the south flank. Towards the close of the year, increased attention was paid to improving the production methods, with encouraging results.

Argentine Oilfields, Limited, continued drilling operations at Cerro Lotena, oil being encountered in several wells, the remarkable thickness of the oil-sands being an outstanding feature.

The Decree of January 10th, 1924, modifying and tightening up the Mining Laws under which oil claims had previously been staked out and prospected, provoked much criticism, chiefly on the score that the new Decree tended to discourage oil prospecting in Argentina. This Decree was followed by the declaration of large areas in which no new prospecting claims would be granted, and no lapsing claims would be renewed. The prompt payment of survey fees was also demanded and led to the surrender of large numbers of claims. It is understood that the Mining Department has in hand a comprehensive revision of the laws pertaining to oil mining.

Despite the considerable home production of crude oil, the total oil imports into Argentina for 1924 amounted to 1,059,234 metric tons, with an approximate market value of about £9,000,000.

Generally the outlook of the oil industry in Argentina at the close of 1924 was very encouraging, not merely from the point of view of the rapidly increasing home production, but also from that of increasing consumption, due to the growing prosperity of the Republic.

Eastern Archipelago.

By James Kewley, M.A., F.I.C., F.C.S.

Intensive geological field work has been carried out with increased geological staff, and the use of rotary drilling both for exploratory and exploitation work has been extended.

In North Sumatra only the Bataafsche Petroleum Mij. have carried out a drilling programme. The production of this area has shown a slight decline.

In South Sumatra the Bataafsche has increased its production by opening up new areas.

In East Borneo the fields of Koetei and Tarakan continue to produce the bulk of the fuel oil and wax crudes of the East Indies. Both these fields, particularly the latter, have yielded increased production. Only the Bataafsche Petroleum Mij. have carried out drilling operations in East Borneo. In Java the total production of the fields showed a slight decrease, and in Ceram the production was maintained.

In Sarawak the production showed a substantial increase over that of the previous year, and it is now no less than 590,000 tons a year, and the Miri field shows good prospects. Exploratory work is being carried out in the State of Brunei.

Natural Gas and Gasoline.—In East Borneo a gas line 100 km. long has been laid to transport surplus gas from the Koetei fields to the refineries at Balik Papan, and a similar but much shorter line, to transport the gas from the fields at Miri to the refinery at Lutong in Sarawak.

Refineries.—The refinery of the Sarawak Oilfields, Ltd., has been extended by the erection of a third complete distillation plant on the Trumble system, and the refinery has been generally improved and remodelled. Trumble plants have also been erected in the refineries at Balik Papan. The Edeleanu plant there has also been extended.

World's Production of Crude Petroleum.

By GEORGE SELL.

As indicated by the preliminary returns of the various oil-producing countries, the world's production of crude petroleum, excluding shale-oil, during 1924 shows a decrease of about one million metric tons, or approximately 0·8 per cent., as compared with the total production for 1923.

The decrease in the production is mainly due to the reduced output in the United States and Mexico. According to preliminary figures, the United States produced 94,302,000 metric tons of crude oil in 1924, this being 3,352,300 metric tons, or about 4·5 per cent., less than the production in the preceding year. With the exception of the Mid-Continent Field, every field in the United States showed a reduction from the 1923 output, the decrease in the Californian production being over four million metric tons.

The following table gives the output and the percentage of the total production by countries for the years 1923 and 1924, and is based on the preliminary returns or, where these are not yet available, is estimated. From this table it will be seen that the production in the British Empire increased by about 7·4 per cent. over 1923, the increase in the percentage of the total world's production being about 0·13 per cent.

WORLD'S PRODUCTION OF CRUDE PETROLEUM.

	1923. Quantity. Metric Tons.	1923. Percentage of Total.	1924. Quantity. Metric Tons.	1924. Percentage of Total.
United States :—				
Appalachian	3,763,340		3,606,530	
Lima-Indiana	320,540		305,070	
Illinois and S.W. Indiana ..	1,266,660		1,164,270	
Mid-Continent	46,461,340		49,163,860	
Gulf Coast	4,436,140		3,685,600	
Rocky Mountain	6,353,740		5,701,470	
California	35,050,140		30,675,200	
Other fields	2,400		—	
	97,654,300	71·446	94,302,000	69·571
Mexico	21,440,000	15·686	20,000,000	14·755
Russia	5,400,000	3·951	6,000,000	4·427
Persia	3,361,000	2·459	4,313,000	3·182
Dutch East Indies	2,048,000	1·498	2,750,000	2·029
Rumania	1,509,800	1·105	1,849,000	1·364
Peru	751,700	0·550	1,000,000	0·738
Venezuela	525,000	0·384	1,000,000	0·738
Galicia	724,700	0·530	757,700	0·559
Argentina	535,000	0·391	663,500	0·490
Japan and Formosa	252,500	0·185	240,000	0·177
Egypt	153,500	0·112	160,000	0·118
France	70,700	0·052	76,000	0·056
Colombia	56,000	0·041	66,000	0·049
Germany	50,000	0·037	60,000	0·044
Czecho-Slovakia	11,000	0·008	13,000	0·010
Italy	4,700	0·004	4,800	0·003
British Empire :—				
India	1,122,000	0·821	1,100,000	0·811
Sarawak	580,000	0·424	625,000	0·461
Trinidad	407,000	0·298	541,000	0·399
Canada	23,250	0·017	23,500	0·017
Other Countries	2,000	0·001	2,500	0·002
Total	136,682,150	100·000	135,547,000	100·000